U.S. Department
of Transportation

**United States
Coast Guard**

Commandant
United States Coast Guard

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COMDTINST M6200.7
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COMMANDANT INSTRUCTION M6200.7

Subj: Public Pool Care Guide

1. <u>PURPOSE</u>. The purpose of this manual is to provide a
    standardized reference guide for swimming pool operations.

2. <u>DISCUSSION</u>.

    a. Public swimming pools are considered an essential place for the
        teaching and enjoyment of swimming and diving skills. Public
        pools must also be viewed by the Coast Guard as an environment
        in which disease can be readily communicated. In fact, many of
        the diseases known to medical science can be transmitted in
        swimming pool water by the simple act of persons ingesting
        water in which they themselves and others have bathed
        (e.g., water containing organisms discharged from the eyes,
        ears, nose, mouth, intestinal tract and sores or infections
        of the skin).

    b. Enclosure (1) has been adopted as a guide for swimming pool
        operations. Page 54 of enclosure (1) defines 5 types of pools.
        All Coast Guard pools should be categorized as a type "A"
        pool. Where reference is made in enclosure (1) to Health
        Officers or proper authorities, this should
        be interpreted as Commandant (G-K), Commander (Ak), Atlantic
        Area or Commander (Ake), Pacific Area.

3. <u>ACTION</u>. Area and district commanders, unit commanding
    officers, and the Commander, Coast Guard Activities Europe shall
    ensure compliance with the provisions of this manual.

                              /s/ L. R. JELLERSON
                                  Chief, Office of Health Services

Encl: (1) Public Pool Care Guide

CONTENTS

INTRODUCTION TO HEALTH AND SAFETY

Mintaining a safe swimming pool environment involves a threefold responsibility:(1)

1. Patrons must be required to conduct themselves in such a manner as to avoid causing personal injury;

2. Dirt and infective material must, to the extent possible, be prevented from entering the pool;

3. Dirt and infective material which does enter the pool must be quickly removed or rendered harmless.

The first of these responsibilities has primarily to do with the public safety as distinguished from the public health. If relates to the physical conduct and deportment of individuals while at work or play within the pool area. The disciplines for governing such behavior have been widely studied and are taught to lifeguards and safety personnel. Since this knowledge is readily obtainable through many courses of instruction, this aspect of pool operation is expressly omitted from this manual.

The second responsibility, like the first, involves almost altogether the discipline and control of human beings. This discipline bears heavily upon the hygienic environment of the pool, however, and is therefore included for discussion here.

The third responsibility involves technical knowledge, special equipment and procedures which embrace the whole science of pool sanitation and disease prevention. Here the operator must develop a knowledge of the chemistry of swimming pool water, the mechanics of filtration, chemical feeding and the hydrulics of the pool recirculation system. It will not be suprising therefore, that this area of discussion comprises the great bulk of the subject matter contained herein.

The manner of presentation of this material is intended to provide perspective in depth rather than to teach the actual manipulation of valves, feeders

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    (1) For a review of typical public health objectives and requirements, see Appendix A.

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and other controls. At times, the discussion may seem too
theoretical. If so, it is because the authors believe that the
operator who has a penetrating knowledge of pool disinfection is
the one best equipped to understand the purely mechanical motions
of pool operation. He is also far better prepared to troubleshoot
the problems which will develop despite the best efforts of a
well trined staff.

CHAPTER ONE

PRINCIPLES OF POOL OPERATION

Pool sanitation in general, and water disinfection in particular, begin with bather supervision and discipline. For the most part, the rules governing good conduct and cleanliness are rather simply enumerated. They are fairly uniform as published in various pool operation publications and as posted on walls and fences of public pools throughout the United States. Unfortunately, however, the mere recitation or publication of the rules does not suggest the seriousness of the need for enforcement. Not until the operator understands the public health involvement can he fully appreciate the importance of insisting that patrons comply with every rules without exception.

For example, an obviously healthy patron wearing a small bandage might seem to present an entirely harmless situation to the untrained bathhouse attendant. The bandage might cover the most common pimple or sore, yet the affected area might well have festered with staphylococcus bacteria. As a highly localized infection, it presents no serious problem to the person afflicted, but it poses a significant health hazard if these same bacteria are washed from the infection and taken into the systems of other bathers.

Much more difficult to relate to public health is the rule requiring nude showers with warm water and soap, or the rule preventing food, drink or tobacco in the pool area. It will be seen in discussions which follow that organic soil (usually harmless in itself) will impose a serious burden upon the chemical disinfectants and filtration system if allowed to accumulate in the pool. Simply permitting patrons to enter the pool unbathed can impair the efficiency of the disinfection system by as much as 50%.

Since the contamination of swimming pool water to some extent is inevitable, some methods must be provided to treat the water and make it safe for swimmers. Such treatment is accomplished by the operation of three inter-related and interacting systems:

1. A system for the recirculation and distribution of pool water;

2. A system for feeding chemicals for disinfection and control of pH;

3. A system for the removal of particles by filtration.

In this chapter these systems are discussed together to explain and emphasize the manner in which they work together to accomplish the ultimate goal of safe, transparent pool water. In subsequent chapters they are discussed individually to provide the reader with detailed knowledge of how each system performs.

Recirculation

The function of the swimming pool recirculation system can probably be best understood if it is thought of as a transportation system which takes water from the pool, delivers it to a station where it can be filtered and chemically treated, and then returns it to the pool. The round trip the water takes is described by the term "turnover." Turnover is expressed as the number of hours necessary to circulate a volume of water equal to the volume contained in the pool. Another method of expression is the number of times in 24 hours that the volume of the pool is circulated; i.e. turnover in 8 hours is a turn-over of 3. Both in theory and practice, it has been determined that the typical public pool should be recirculated continuously at the rate equal to one turnover in each six to eight hour period. The Law of Dilution as developed by Gage and Bidwell suggests that such a turnover rate will provide 95% to 98% dilution of soiled pool water with water that has been filtered and chemically treated. Gage and Bidwell's law has been largely upheld in practice, and the six to eight hour turnover rate has generally become a standard for the operation of public pools subject to periodic or frequent heavy bather loads.

Filtration

The removal of soil particles by filtration is closely related to the function of disinfection by chemical treatment. Each function, however, has a separate and distinct contribution to make to the health environment of the pool. These distinctions must be thoroughly understood if the reader is to fully comprehend the treatment of swimming pool water.
The filter plant is of some value for its capacity to remove bacteria and disease producing organisms. But primarily, its function is to remove soil particles which, if not removed, would increase the need for chemical treatment and reduce the germ killing and oxidizing power of disinfection chemicals.

Disinfection

While filtration is a relatively simple process of physically removing soil particles, disinfection is a considerably more complication process involving rather intricate chemistry. Ideally, disinfection is accomplished by introducing a germ-killing chemical to pool water in sufficient strength to

provide nearly instantaneous destruction of bacteria. Chlorine, one of
a group of chemicals referred to as "halogens," is the disinfecting
agent most commonly used in public pools and is therefore used as a
term of reference henceforth in this text. (Its use does not infer
that other acceptable agents for disinfection could not be substituted
in the particular frame of reference, such as bromine, and others of
the halogen family.)

When chlorine is added to pool water, it combines chemically with the
oxygen and hydrogen components of water to produce hypochlorous acid
(HOCL). Hypochlorous acid, in turn, attacks and kills bacteria
(see Figure 1).

Disinfection may also be accomplished with bromine and the chemistry
involved is much the same. The chemical reaction produces a mild acid
which possesses germ killing properties approximately equal to those of
hypochlorous acid.

Regardless of the disinfecting agent used, the primary goal is the same:
to provide a uniformly distributed disinfection and oxidation residual
of sufficient strength to rapidly destroy disease producing organisms
which may be introduced to pool water.
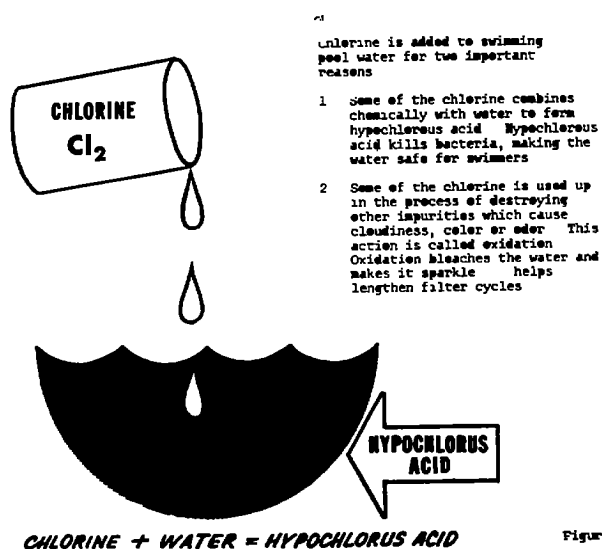
CHLORINE + WATER = HYPOCHLORUS ACID   Figure 1

Chlorine is added to swimming
Chlorine + Water = Hypochlorus Acid   pool water for two important
reasons:

1. Some of the chlorine combines chemically with water to form
    hypochlorous acid. Hypochlorous acid kills bacteria, making the
    water safe for swimmers.

2. Some of the chlorine is used up in the process of destroying
    other impurities which cause cloudiness, color or odor. This
    action is called oxidation. Oxidation bleaches the water and
    makes it sparkle.helps lengthen filter cycles.

Although chlorination is practiced primarily for reasons of disinfection by direct kill of microorganisms, it serves another very important and useful purpose. The commonly used chlorine and bromine products possess strong oxidizing properties which cause them to react with and destroy many foreign materials other than bacteria. Many of these materials, if not destroyed by oxidation, would impart undersirable characteristics to the water such as turbidity, color or odor. This chemical destruction of soil plays an important part in the filtration/disinfection process, as will be discussed in later chapters.

pH Control

pH is the least understood and most mysterious aspect of pool maintenance and is the most likely of the three controls to be treated carelessly or ignored altogether. But the skilled pool operator will be as concerned with pH control as he is with disinfection and filtration equipment.

pH is a chemical abbreviation used to describe the presence of the hydrogen ion in water. It is somewhat inaccurate to do so, but pH is more often explained as a measure of the relative acidity or alkalinity of water. This will be the frame of reference here, however, until the definition is more carefully made in the next chapter.

pH is measured on a scale of numbers ranging from 0 to 14. The midpoint seven (7) is said to be precisely neutral, above which alkalinity becomes progressively greater, and below which acidity becomes progressively greater. In swimming pool water it is important to maintain a slightly alkaline condition between 7.2 and 7.8 (see Figure 2).

Problems develop when this range is exceeded on either side. A high pH, for example, can cause precipitation of dissolved minerals such as calcium and iron with resulting discoloration and turbidity. Low pH can cause serious corrosive damage to metals in the recirculation system. Both high and low pH will cause eye irritation.

From a public health viewpoint, the most serious effect of improper pH control is seriously reduced efficiency of the disinfection process. As pH rises above 8.0, chlorine reactions tend to produce an abundance of hypochlorite ion (OCL) rather than the desired hypochlorous acid (HOCL) and germ killing oxidizing powers are greatly reduced. A procedure of super chlorination can be successfully used with high chlorine values and high pH under careful controls and there is literature available for those interested. Also "break point" chlorination is covered in a later chapter and is effective in burning out the ammonia content of the pool water. As pH value continues to rise the chlorine residual progressively weakens and may become virtually useless for disinfection and oxidation purposes above pH 8.5.

It often surprises the inexperienced pool operator to discover that serious water problems have developed despite the fact that filters are functioning properly and chlorine residual reads strong in the chlorine test procedure. In such cases, the problem can often be traced to the fact that pH has been permitted to drift well into the undesirable zone above 8.0 or below 6.8.

TOO ALKALINE

9

TOO ALKALINE

pH too high. Disinfection and oxidation properties of chlorine are reduced. High pH may also cause clouding and discoloration of water and eye irritation.

Add acid to lower pH to safe range.

8

7.8

SLIGHTLY ALKALINE

◁ IDEAL

7.2

7

TOO ACID

pH too low. May cause serious corrosion damage to recirculation system and eye irritation.

Add alkali (soda ash) to raise pH to safe range.
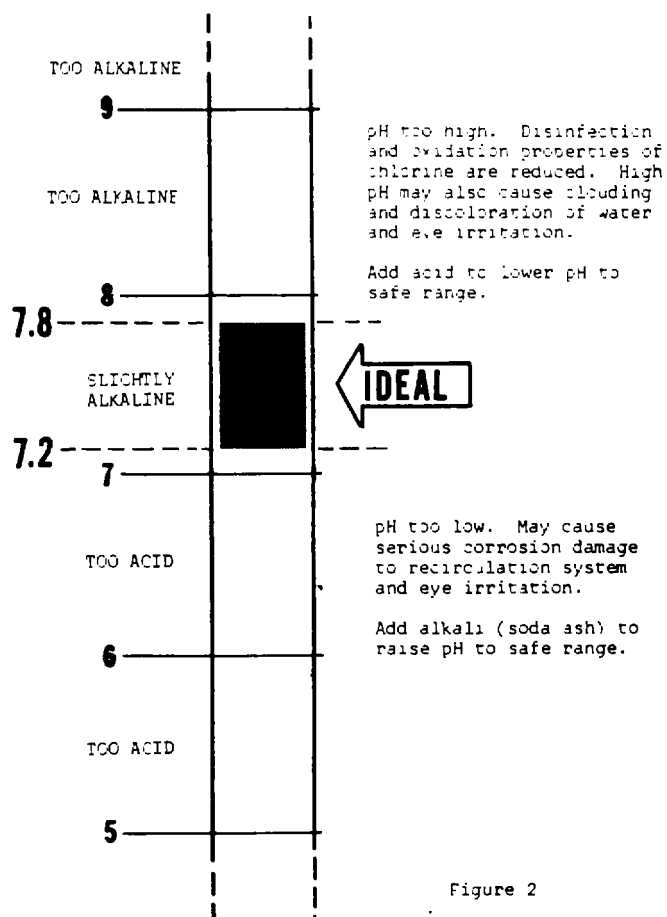
6

TOO ACID

5

Figure 2

Ideal 7.2 to 7.8 pH Chart

CHAPTER TWO

THE CHEMISTRY OF CHLORINATION

The chlorination of swimming pool water involves some rather intricate chemistry A full understanding of the subject would require an extraordinary academic preparation coupled with substantial field experience. Since neither of these qualifications can be provided in a handbook or short course, this manual must deal with summary aspects of the subject.

In order to do so it is necessary to use some chemical terminology, for this is the only language which can be used to discuss the subject. But it is hoped the chemical terms which are used will be made understandable by the context in which they are used, even if the full scientific meanings remain vague. At times, the scientific term is used in a manner which would be regarded as inaccurate by the chemist. When this is done it is for the sake of simplicity and is believed justifiable for this reason.

Many manuals on pool care treat chlorination too briefly to reveal the depth of the subject, while most technical journals must dwell too thoroughly in text book chemistry to be understood by the layman. It is hoped this manual will help bridge this gap by providing an understandable marriage of theory and practice.

Swimming pool water is chlorinated for two important reasons:

1. DISINFECTION - to kill bacteria and disease producing micro-organisms which might infect bathers if not destroyed;

2. OXIDATION - to react with and destroy other contaminants such as algae, body oil, minerals, dust and other materials which cause color, odor and turbidity.

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For example, the term chlorimide is used to describe a family of nitrogen-chlorine compounds resulting from intentional chlorine stabilization. As used, the term embraces chloramides as well as chlorimides. Although precise accuracy would require that the chemical distinction between the two be made, it is believed the technical discussion required would be more confusing than helpful.

In order for disinfection and oxidation to be accomplished, a chemical reaction between chlorine and water (hydrolysis) must take place with the resulting formation of hypochlorous acid (HOCL). Regardless of the chlorine source material(3) used, the desired end-product of chlorination is hypochlorous acid. This is the chemical agent which reacts with and destroys bacteria and the other undesirable contaminants in pool water.

Hypochlorous Acid (HOCL) Formation is Governed by pH(4)

Hypochlorous acid is not necessarily produced by the simple act of mixing chlorine and water. The pH of the water being treated determines whether the hydrolysis reaction produces an abundance of the desired hypochlorous acid or whether the primary product is hypochlorite ion (OCL)(5), a relatively weak and ineffective oxidizing agent.

At pH 7.2 approximately 60% of dissolved chlorine will exist as hyphchlorous acid. But as pH value increases the amount of HOCL decreases and the amount of hypochlorite ion increases. At pH 8.5 a point is reached at which dissolved chlorine exists 90% as (OCL) and only 10% as (HOCL). Thus it can be seen that the disinfection and oxidation properties of chlorinated water are six times as great at pH 7.2 than at 8.5. For this reason, pH 7.8 has been generally adopted as the upper limit for swimming pool water containing chlorine residual in the range of 0.5 to 1.0 parts per million (ppm).
If pH is allowed to exceed this limit, chlorine dosage correspondingly increased in order to provide an adequate supply of hypochlorous acid.

Other Reasons for pH Control

In addition to its serious effect upon disinfection and oxidation, pH fluctuation must be avoided for other reasons. At high pH dissolved minerals such as iron and calcium will precipitate, thus adding turbidity and increasing

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(3) Formation of hypochlorous acid (HOCL) is the goal regardless of whether the pool is chlorinated with elemental (gas) chlorine or one of the chlorine bearing compounds such as calcium hypochlorite, sodium hypochlorite, chlorinated cyanurate, etc.

(4) For a detailed discussion of pH effect upon chlorine reactions, see Appendix B.

(5)As pH rises the hydrogen component (H) dissociates from the HOCL compound leaving the (OCL) hypochlorite ion. (OCL) is an extremely weak oxidizing agent.

dirt removal demand upon the filter system. High pH in the presence of high total alkalinity will contribute to scaling of filters, heaters and piping.

As pH drops below 7.0 the condition of the water becomes progressively acid, producing eye irritation, corrosion and other undesirable effects. Below 6.5 water becomes corrosive and will cause damage to metals in the recirculation system.

The pH ranges from 7.0 to 7.2 on the lower side and from 7.8 to 8.0 on the upper side are not objectionable, but they might well be thought of as safety zones to support the ideal range of 7.2 to 7.8.

Free Vs. Combined Chlorine

The potency of chlorine is importantly affected by the ammonia content as well as the pH of the water. Ammonia is naturally present in virtually all surface exposed bodies of water and even more so in swimming pools since skin excretions and urinary discharges are ammonia sources. When dissolved chlorine exists predominantly as hypochlorous acid (HOCL) the residual is said to be "free available" chlorine ... "free" to react with bacteria and other forms of soil. When chlorine reacts with ammonia the resulting compounds are called chloramines and the chlorine is said to exist as "combined" rather than "free" residual. The chloramines are undersirable since, like hypochlorite ion (OCL), they possess greatly reduced oxidizing and germicidal power.

The extent to which chlorine reactions produce chloramines rather than hypochlorous acid is governed largely by the amount of ammonia present. For the sake of description, chlorine might be said to prefer to react chemically with ammonia rather than with bacteria and soil. Thus, if sufficient ammonia is present in pool water the chlorine will exist largely as combined residual chloramine (6) and oxidation and disinfection activity will be greatly reduced.

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    (6) Chloramine cannot be readily distinguished from free chlorine in the typical test kit procedure since both are reactive with the orthotolodine reagent. The first "flash" reading is normally regarded as a measure of free chlorine, but this reaction is followed immediately by a deepening of the test sample color due to reaction with chloramine. Therefore, if ammonia is abundant in the water being tested the operator might well be misled by the reading.

Super Chlorination

In the early history of swimming pool chlorination it was common
practice to intentionally stabilize chlorine by adding ammonia to the
water. Since it had been observed that ammonia improved chlorine
retention and prolonged the life of chlorine residual test readings, it
was reasoned that disinfection properties were enhanced by the method.
Later studies revealed the poor disinfection properties of chloramines
and the practice has given way to a preference for burning out ammonia
compounds through super chlorination ... sometimes referred to as
"breakpoint" chlorination.

Breakpoint chlorination is accomplished by increasing chlorine dosage
to a point at which all ammonia compounds in the water are completely
oxidized and removed by chlorine reaction, after which point all
dissolved chlorine exists as free available hypochlorous acid (HOCL) or
hypochlorite ion (OCL). The amount of chlorine required to reach
breakpoint in a given situation depends upon the amount of ammonia
present. Dosage instruction cannot, therefore be expressed in pounds
or parts per million. But occasional super chlorination to 4 or 5 ppm
in the typical public pool will provide an acceptable means of assuring
free residual chlorine as a routing matter.

Intentional Chlorine Stabilization

While the formation of chloramines in a swimming pool is considered
objectionable, the stabilizing of chlorine with nitrogen compounds
other than ammonia is considered desirable under some conditions. On
the face of it such a practice would seem highly inconsistent with
conclusions presented in the foregoing discussion, but the benefits to
be derived become clear when the chemistry of chlorination is
carefully studied.

The hypochlorous acid molecule is highly desired for its oxidizing
properties, but it is a highly unstable compound which rapidly
dissipates in the presence of sunlight. This instability results in
considerable chlorine waste, since free chlorine is rapidly destroyed
even if it is not usefully consumed in reactions with bacteria and
soil. Some degree of stabilization would therefore be desirable if
such stabilization would slow the rate of chlorine dissipation
without appreciably sacrificing oxidation and disinfection activity.
Recently developed practices in swimming pool chlorination
suggest that such stabilization can be accomplished satisfactorily
with the use of cyanuric acid as the stabilizing agent. Chlorine
reaction with cyanuric acid produces a relatively stable compound
identified as chlorimide and, as in the case of chloramine formation,
the dissolved chlorine exists predominately as combined residual.
However, the chlorimide seems to possess significantly greater
oxidation and disinfection properties than the chloramine group and
is therefore an acceptable disinfection agent, whereas

chloramine is not. Chlorimide reactions can also be produced with sulfa mic acid and chlorinated chyantoins, but the use of these products is far less widespread than the chlorinated cyanurates.

Laboratory and field studies of cyanuric chlorination technique suggest that, although the disinfection and oxidation properties of chlorimide are less than those of free hypochlorous acid, the loss can be at least partially offset by maintaining higher residuals of dissolved chlorine. It is generally believed that chlorine residuals in the presence of cyanuric acid should be maintained at 1.0 to 1.5 ppm, whereas 0.5 to 1.0 ppm is acceptable when free unstabilized chlorination technique is practiced.

The chlorinated cyanurates are used more commonly in private residential and small commercial pools at this writing. In larger public pools, subject to occasional or frequent heavy bathing loads, systems which provide free unstabilized chlorine residual are most frequently employed.

Control of pH and Chlorine Residual

Oxidation and disinfection of swimming pool water can be accomplished only when adequate chlorine residual[7] and proper pH value is maintained. The pool operator must therefore understand what factors in the pool environment cause pH fluctuation and chlorine dissipation, and how to control those factors through proper chemical feeding practices.

Chlorine consumption and feed rates are the easier of the two variables to understand. In prior discussion it was explained that chlorine reacts with and destroys virtually all organic and inorganic compounds which may be found in pool water. In the process the chlorine itself is destroyed and must be replaced. Obviously then the rate of feed is dependent upon the quantity of soil present in the water which, in turn, is largely dependent upon the bathing loads, bather preparation, weather, etc. It must also be remembered that free available chlorine dissipates even if it is not consumed by soil, so some chlorine feed is necessary even during periods when the pool is not in use.

It is quite generally believed among knowledgeable technicians and public health personnel that free chlorine residual of not less than 0.5 ppm should be maintained at all times in the public swimming pool. The better and safer practice is to feed at rates calculated to provide 1 ppm residual, with

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(7) Meaning adequate residual of chlorine or its eqivalent disinfecting agent such as bromine.

occasional super chlorination to 2 to 5 ppm, depending upon ammonia con-
tent and chlorine demand of the water.

Chlorine Test Procedure

The presence of chlorine is rather simply tested by use of a
colorimetric test using orthotolodine as a reagent chemical. The test
is usually made periodically throughout the day with the operator
adjusting the chemical feed rates to compensate for the rise or fall
of residual as shown by the tests. The experienced operator learns
to sense chlorine demand by observing bather loads, weather
conditions, temperature, sunlight and other influences. His periodic
tests then are more often confirmation of proper feed rates than
signals that rates need to be changed.

The control of pH can be considerably more complicated than control of
chlorine concentration. The chemistry of the pH factor itself is
considerably more subtle than chlorine hydrolysis, and the factors
which cause pH fluctuation are usually quite confusing to the
non-chemist. The methods of control can be made reasonably clear,
however, even if the chemistry is not understood. pH control begins
with knowing the pH of the water supply used initially to fill the
pool and thereafter to make up water loss. Employing the
conventional colorimetric test procedure using phenol red reagent,
the pH of the raw water is ascertained and then adjusted, if necessary,
to the range of 7.2 to 7.8 (8).

Subsequent pH fluctuation is caused largely by the type of chlorine
source used for oxidation and disinfection. Gas (elemental) chlorine,
which is the most commonly used chlorine source in large public pools,
drives pH downward, while the commonly used calcium hypochlorite and
sodium hypochlorite sources tend to raise pH. Thus, if gas
chlorination is practiced it is necessary to concurrently feed a
substance to counteract the pH lowering effect of the gas chlorine.
Soda ash, fed pound for pound with chlorine feed, is normally used
for this purpose.

To counteract the pH elevating effects of sodium hypochlorite and
calcium hypochlorite an acid counteractant must be used. Normally,
pH control during hypochlorination is accomplished by feeding muriatic
acid or solutions of sodium bisulphate.

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    (8) If the raw water is found to be well above or below the
desired range, it is usually adjusted to the opposite end of the
desired range as a hedge against its tendency to drift once again to
the original reading. Raw water reading pH 8.5, for example, should
be adjusted to 7.2 or 7.3.

When the chlorinated cyanurates are used, the effect upon pH has often been found to be very slight compared with gas chlorine and hypochlorites. Consequently, pH adjustment is normally accomplished by occasional manual dosage of the counteractant rather than by continuous feed concurrently with the feed of the chlorine source.

Total Alkalinity

There are a number of other environmental conditions which can affect the pH of swimming pool water. Their enumeration and discussion, however, would probably misplace the emphasis upon chlorination as the principal factor. For the most part, it is enough to say that when pH strays from the ideal zone of 7.2 to 7.8, regardless of cause, it should be promptly corrected.

The operator must understand, however, there are conditions under which pH may respond to adjustment in a very erratic and unpredictable way. For example, a very high pH of 9.0 might be adjusted to 7.8 by the addition of muriatic acid, only to quickly ascend the scale again to 9.0 within a few hours. Or, the addition of a very small amount of corrective acid or alkali might produce a major response, sending the pH radically to an extreme high or low reading. Such reactions are attributable to the "total alkalinity" of the pool water, and may indicate the need for corrections other than routing addition of acid or soda ash. It is becoming common practice to equip the public pool with testing equipment which can be used to measure total alkalinity as well as pH, thus enabling the operator to make the neces-sary adjustments.

Total alkalinity might be said to be a measure of the extent to which a given water is buffered or made to respond to pH adjustment.
A water containing very low total alkalinity will respond redically to pH correction while a water containing very high total alkalinity might respond very little or hardly at all to the addition of acid or alkali.

It is generally agreed that swimming pool water should contain a minimum of 50 ppm and a maximum of 100 ppm total alkalinity. If the test procedure indicates a need for correction, it can usually be made by treating the water once, or for a short period of time, after which pH control is routinely accomplished by the methods discussed above. If the total alkalinity is found to be too low it can usually be corrected by the addition of a sufficient quantity of calcium carbonate (CA CO(3)) to bring the level to 80 ppm. If it is found to be too high the corrective measure may be somewhat more complicated. Essentially the correction of undesirably high total alkalinity calls for the addition of muriatic acid. However, a single dose of a suffi-cient quantity of acid to reduce pH to 7.5 might not be a sufficient dose to

hold pH at this desired level. The reading may consequently rise to a high reading once again within a few hours. When such a condition prevails, the acid dose must be repeated until such time as the pH stabilizes at a desired level and total alkalinity is brought down to less than 100 ppm.

CHAPTER THREE

PRODUCTS COMMONLY USED
FOR DISINFECTION AND OXIDATION

Historically, chlorine has been the primary disinfectant used in swimming pools, although bromine has also been widely used. Both chemicals are commonly referred to as halogens, a chemical term used to describe the four elements which are related in the atomic table, chlorine, bromine, iodine and fluorine. Iodine has also shown some promise as a pool disinfectant and is the subject of considerable experimentation at the present time. However, since iodine has not become widespread in use, this discussion is confined to the chlorine and bromine products.

Chlorination, as the term implies, is the practice of introducing chlorine to pool water either in its elemental form or by adding a chlorin-bearing compound to the water. Regardless of the product used or the method of application, the goal is to achieve a chlorine residual possessing strong oxidizing and disinfecting properties. There are four chlorine sources and two bromine sources which might be said to have common acceptance as disinfection products. Algicides are also useful in assisting the disinfection process and are therefore included for discussion.

All pool chemicals must be handled and stored in accordance with the manufacturer's instructions. It should be remembered never to mix chemicals together outside of the pool; rather use the pool as a buffer in the actual application.

Elemental Chlorine

Elemental chlorine is a greenish colored gas at room temperature. It is packaged under pressure as a liquid in metal bottles and is fed into the recirculation system by equipment of highly specialized design. If it escapes from its container or feeding apparatus it will aggressively attack virtually all surroundings, especially if water or moisture is present. It is also highly toxic to man.

Because of the hazardous nature of chlorine gas, its proper handling must be thoroughly understood by those responsible for containers and operating feeding devices.

Normally, the cost of chlorine in its elemental form is considerably less than the cost of chlorine obtained from commercial chlorine-bearing compounds. It is therefore the most commonly used chlorine source in the large public pools where feed rates and consumption are high. The cost of the extra soda ash required for this type of chlorine must be taken in account in making any cost comparison.

Calcium Hypochlorite

Calcium hypochlorite is a relatively stable compound of chlorine and calcium, commercially packaged either as a coarse powder or in tablet form. It is a safer material than chlorine gas with respect to handling and feeding, but it may present serious problems if spilled or scattered in a moist or wet environment or if oxidizable material is introduced to the container.

When applied to swimming pool water calcium hypochlorite reacts much the same as chlorine gas. It tends to release free chlorine from the stabilizing agent and the resulting hydrolysis produces varying chlorine reactions. Due to the relatively compact nature of the package material, calcium hypochlorite is a popular chlorine source in small and medium sized public pools. Although it is a more costly source than gasious chlorine (in net yield) this disadvantage is somewhat offset by the relative ease and safety of handling, storage and feeding. By weight the most commonly used calcium hypochlorites will yield 70% available chlorine.

Calcium hypochlorite can be manually fed directly into the pool from hand held containers to either facilitate super chlorination or as an alternate feed in the event of equipment failure. Normally, however, it is mixed with water in tanks or feed crocks and the clear liquid is fed to the recirculation system by means of mechanical feeders. Such feeders are adjustable to provide controlled rates of continuous or intermittent feed.

Sodium Hypochlorite

Sodium hypochlorite is a liquid compound of chlorine, water and sodium which is usually packaged in carboys or drums. If properly stored, it will yield 10% to 15% net chlorine depending upon its method of manufacture and the age of the material. Like calcium hypochlorite it is relatively safe and easy to handle and feed, but it is also a hazardous product to spill. Applied to pool water the hydrolysis reactions are essentially like those of other chlorine sources.

Because of the weight and bulk involved, sodium hypochlorite normally is used to chlorinate smaller pools ranging in size up to 75,000 gallons. In terms of disinfection chemistry, there is no reason to limit its use with respect to pool size, but it can be readily seen that a great volume of source material would be required to adequately supply larger public pools.

Mechanical feeding is accomplished in the same manner and by the same type of equipment used to feed calcium hypochlorite mixed with water. Sodium hypochlorite need not be premixed with water since it is a feedable liquid in its packaged form when the proper feeder is used.

Lithium Hypochlorite

Lithium hypochlorite is another of the dry chlorine compounds. It is a free-flowing granular sanitizer, containing 35% available chlorine. The product is an inorganic material with the chlorine immediately available as in the other inorganic chlorine vehicles. It is completely soluble in pool water, and may be applied directly to the pool by broadcasting on the water, or may be made up in a solution and dispensed through a chlorinator. It is stable under all normal storage conditions, and may be stored for extended periods without appreciable loss of available chlorine. It is an acceptable product for swimming pool sanitation and has all of the attributes common to the other hypochlorites.

Elemental Bromine

While chlorine in its elemental form at room temperature is a gas, pure elemental bromine is a heavy red liquid and, like chlorine, is an aggressive oxidizing agent. Bromine is a dangerous chemical in untrained hands.

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(9) See section headed "Intentional Chlorine Stabilization" in Chapter 2.

If spilled from its container, bromine will attack virtually any substance in its path. Even the fumes from an uncapped container can cause injury to persons and damage to surroundings.

As a disinfection product, bromine has been demonstrated to be equal to chlorine in bactericidal efficiency, although the chemistry is somewhat different. The hydrolysis of bromine produces hypobromous acid which, like the hypochlorous acid product of chlorination, is the agent which destroys bacteria and oxidizes undesirable soil.

Commercially, elemental bromine is packaged in glass jugs specially crated to guard against shock damage and breakage in shipment and handling. The material is fed to the recirculation system through a brominator which provides for dissolving liquid bromine in a crock of water near the point of injection.

Elemental bromine is somewhat more costly for equivalent disinfection values than gas chlorine, and normally somewhat more expensive than the hypochlorites and cyanurates. (10)

Organic Bromine

In recent years bromine has become available commercially for pool sanitation in bromine-containing organic compounds commonly referred to as hydantoin or "stock" bromine. In such forms bromine can be compared with hypochlorites and cyanurates except it is twice as heavy as chlorine but not as volatile in the pool atmosphere. Such products are more costly than elemental bromine and therefore less likely to be used in the treatment of large public pools. They are far less hazardous to handle than elemental bromine however, and therefore possess distinct advantages in dosing small and medium size pools where cost is a lesser consideration.

Organic bromine is more costly than most of the disinfection products discussed here. It is a slow dissolving solid which is normally fed to the

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(10) The cost factors of the various disinfection products under discussion here are affected by proximity to point of manufacture, local pricing practices and other factors which influence ultimate consumer cost. These factors cannot all be equated in this discussion.

recirculation system from a pressure vessel in which it is eroded by the washing action of the recirculating stream of water. As a practical matter, the organic bromine compounds may be less adaptable to precisely controlled feed rates unless metered by means of positive displacement devices. The method has been systematically effective, however, in disinfection of private pools. Also, claims have been made that longer swimmer immersion can be effected, especially for competitive and training pools, where this is a factor.

Algicides

An algicide is a chemical additive used to kill and prevent the growth of algae in swimming pool water. Algicides are formulated for their specific toxicity to algae (11) as an aid to disinfection chemicals. Although algae growth can be inhibited by the disinfection chemicals alone, there seems to be increasing acceptance and use of algicides for reasons of economy since their use reduces chlorine demand.

Unlike the relatively unstable hypochlorous acid produce of chlorination, algicides are highly stable and residuals can therefore be sustained by hand dosing once or twice per week. The most commonly used commercial algicides are compounds containing copper, quaternary ammonium chloride or phenol mercuric acetate.

Other Disinfection Products and Methods

Silver has been used experimentally in the purification of water for many years but has never gained acceptance among public health authorities. There are many limitations which need not be discussed here. The primary shortcoming is the relatively prolonged "contact time" required for bacterial kill. It is also noted that silver has very limited oxidizing properties which have been discussed elsewhere as essential to overall treatment of pool water.

Ultraviolet light has been discredited as a process for the treatment of pool water. Although the ultraviolet light rays will destroy bacteria in a single exposure at a single location, there is no known way to disperse this germ-killing power in the body of pool water. Without such dispersion

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(11) Algae is a form of aquatic plant life, the most common strain of which imparts a green cast to water. Although harmless in itself, algae is objectionable in pool water since it increases chlorine demand, thus reducing disinfection and oxidation activity. Algae will grow rapidly and abundantly in untreated pool water.

of the germ-killing residual throughout, the pool swimmers run the risk
of infection. Ultraviolet light disinfection would seem to require a
virtual floodlighting of the entire pool at all times. Such a
practice would involve risks greater than those of bacterial infection.

CHAPTER FOUR

FEEDING GAS CHLORINE

Gas chlorination of swimming pools is accomlished by dissolving chlorine
gas in a flowing stream of water and then injecting this chlorine rich
stream into the recirculation system. The gas and water are mixed in a
chlorinating device which is adjustable to control the feed rate, which
is usually scaled in terms of pounds per 24 hours. Thus a 50 pound
chlorinator is one capable of feeding 50 lbs. of chlorine per day; a
100 pound chlorinator is capable of feeding 100 lbs. per day, etc.

The choice of size of chlorinator needed for any given pool is
determined by the size of the pool itself in total gallons or GPM of
the recirculation system. One common sizing formula accepted by most
designers is to divide the GPM of the system by 8 with the quotient
expressing the pounds per day capacity needed. Thus a pool being
recirculated at 800 GPM should be equipped with a 100 pound
chlorinator. Although this formula has the effect of sizing a machine
at three to four times the average capacity needed daily, as a
practical matter the machine has not really been oversized. What
appears to be oversizing is actually a safety precaution since
there are hazards involved in high volume feeding chlorine from a single
tank through a single chlorinating device. (12)

The actual rate of feed needed to properly chlorinate a given pool
cannot be predicted by any pat formula. As noted in the earlier
discussions of the disinfection mechanism, the chlorine demand of the
pool is determined by the bacteria and dirt loading of the pool, the
size of the bathing load, the temperature and many other factors. As
these contaminating influences fluctuate, the rate of chlorination must
be adjusted upward and downward accordingly. Of course, the
experienced pool operator soon learns "approximate settings" which
will properly chlorinate under these varying conditions. But these
settings are learned only by trial and error adjustments carefully
based upon test kit readings of the pool water itself.

Since the chlorine feed rate has a corresponding influence upon pH, it
is equally important for the operator to adjust chemical feed devices
which are feeding pH control chemicals. Since gas chlorination
lowers pH, the

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        (12) High volume feed, for example, may cause frosting and fouling
of the feeding apparatus.

feeding of soda ash alkalizing agent must be increased when chlorine feed is boosted and vice versa. Even so, the required feed rates are not precisely proportional, and it is therefore necessary to determine the alkaline feed rate in the final analysis by reading the water condition in the pool with a pH test kit. (13)

The substance of gas chlorination equipment operator training stresses the safe handling of chlorine cylinders, connecting and disconnecting the chlorinators, and emergency procedures.

In view of the hazards involved, it is obviously impossible to properly train an operator of gas chlorination equipment in a classroom or from text material. It seems wise, however, to include a fairly comprehensive narrative for those who may wish to pursue the subject further. Accordingly, the balance of this section reviews the subject almost entirely from the viewpoint of operator safety rather than from the viewpoint of pool water disinfection.

Equipment and Operations

All containers used in the transportation of liquified chlorine gas are controlled by strict federal or other governmental regulations. Cylinders of the type used in pool chlorine supply are of seamless steel construction with an operating valve equipped with a safety device in the form of a fusible metal plug. The fusible plug is designed to melt at 158 F. to permit escape of chlorine gas as an alternative to tank rupture. The fusible plug should not be tampered with under any circumstances.

The valve itself has a non-standard pipe thread requiring a special wrench. The special wrench is intended to signal "danger" and to discourage anyone from using pliers, wrenches or a hammer to force connections or otherwise depart from standard handling technique.

When connecting a cylinder to the chlorinator, special precautions should be taken to insure the security of the connections before the operating valve is opened. After the valve has been opened, the connection should be tested for the presence of leaks too small to be detected immediately by odor or by sound of escaping gas. This is accomplished by holding an uncapped bottle of ammonia near all connections. Even the smallest leaks of chlorine gas will become immediately apparent as a chemical reaction

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(13) In practical operation elemental chlorine and soda ash are fed approximately pound for pound.

between the chlorine and ammonia produces a white vapor cloud of ammonium chloride.

When a cylinder is empty the valve should be closed and tested for leaks and the valve hood replaced. The empty tank should then be treated and handled as though full until it is removed from the premises.

Chlorine cylinders and equipment should be located in fire resistant, separate and enclosed indoor areas, accessible only to authorized persons. Such areas should be clean, light, dry and well ventilated. At least two means of access and exit should be provided in all areas where cylinders are stored and handled. One or more chlorine gas masks should be instantly available outside the storage room. Cylinders should be stored securely fastened in an upright position in such a manner that they cannot tip or fall, and in such a location as to avoid the possibility of heavy objects falling upon or striking them.

Cylinders should be moved on a properly balanced hand truck having a cradle or clamp support near the top of the tank. The cylinder should not be lifted by its protection hood or rolled using the hood as a valve or as a pivot.

Chlorine gas cylinders should never be stored or handled near heat pipes or other external sources of heat. At room temperature a full chlorine cylinder contains approximately 90% liquid and 10% gas. As temperatures increase the resulting internal pressures increase the percentage of liquid and reduce the percentage of gas. At approximately 154F. the container is completely filled with liquid and any further elevation of temperature will cause the fusible plug to melt, permitting a rapid escape of the contents of the tank.

Emergency Preparedness

Safety in handling gas chlorine depends upon the effectiveness of employee education, proper safety instruction, intelligent supervision and the use of safe equipment. Employees should be thoroughly informed of the hazards of improper handling.

When a chlorine leak occurs, authorized trained personnel, equipped with suitable gas masks, should investigate. All other persons should be cleared from the area immediately and kept away until the cause of the leak is found and the trouble corrected. If the leak cannot be handled promptly, the nearest office of any chlorine supplier or producer should be called immediately for assistance.

Any person overcome by or seriously exposed to chlorine should be moved at once to an uncontaminated area, and should be kept completely at rest and warm until medical assitance can be obtained. If breathing has ceased, immediately apply artificial respiration or use approved inhalation equipment or oxygen.

CHAPTER FIVE

FEEDING LIQUID CHEMICAL SOLUTIONS

Liquid chemicals are used in swimming pools for three principal
functions: disinfection, pH and alkalinity adjustment, and
flocculation. Also, diatomaceous earth filter aid is fed as a
liquid slurry, but it is not treated in this chapter. For
disinfection, by far the most common chemicals are the
chlorine sources. For pH and alkalinity control typical chemicals are
soda ash, muriatic acid and sodium bisulphate. For flocculation filter
alum is the common choice with soda ash being added to provide
sufficient alkalinity. Our discussion, however, is to be confined
in this section to the chlorine-bearing liquids.

For disinfection by chlorination, there are three primary compounds used
in solution type feeders: calcium hypochlorite, chlorinated cyanurates,
and sodium hypochlorite. The first two are normally dry powders. The
third is a liquid. In practical swimming pool operation there are
limitations on the strength of the solution which may be prepared from
each of these chemicals. The liquid sodium hypochlorite is typically
furnished in concentrations of 15% or less.

It may be diluted or it may be fed full strength. In preparing
solutions of the dry cyanurates or calcium hypochlorite, manufacturers
recommendations should be followed, and suggested solution strengths
are typically 2% to 5%.

Solution preparation and storage is now far simpler than it once was,
thanks to self-supporting polyethylene and fiberglas tanks. The heavy
metal and ceramic tanks which once were so common are less often used
today.

In general, it is desirable to use the largest solution reservoir,
weakest solution strength and highest chemical feeder output setting
which is consistent with the space, personnel and facilities available.

The large solution reservoir makes it possible to prepare at one time,
a batch which will last a relatively long period. If calcium
hypochlorite (or other residue chlorines) are used for preparing the
solution, it is wise to use the two-tank system if the space is
available. That is, mix one tankful, and allow the precipitate or
insoluble material to settle before the intake of the chemical feeder
is placed in the tank. Then while feed is being taken
from the first tank, another supply may be mixed in the second tank and
allowed to settle. Tanks then can be alternated and the insoluble
sludge

which tends to settle out can be cleaned from each tank prior to mixing a new batch. It is possible, of course, to install corrosion resistant plastic drain valves in plastic tanks to make this job easier.

Another advantage of using a relatively large solution reservoir is that it permits the use of more dilute solutions which retain strength longer. This, in turn, permits operation of the chemical feeder at a higher rate, thus increasing its volumetric efficiency and accuracy, making possible better dispersal of the sanitizing agent in the water.

It is good practice to cover solution tanks both for the protection of the solution contained, and to prevent the possible spread of vapors or fumes. Some chemical feed systems provide combination tank and feeder assemblies in which the cover may serve as a support for the feeder. The feeder may also be located at the side or below the tank.

It is important that solution tanks are properly maintained because clean solutions assure accuracy and trouble free operation of the chemical feed system.

The chemical feed unit itself is composed of an assembly for handling the chemical solution and some kind of mechanism for supplying the energy necessary to inject the chemical solution. Most chemical feeders used in public swimming pools are the positive displacement type, although other types including drip feeders and venturi or differential pressure feeders are being used. This presentation is concerned with the positive displacement type since most regulatory agencies require systems which permit accurately metered feed.

Most such feeders have at least two check valves and a piston or diaphragm to provide a means for transmitting the energy of the drive mechanism to the pumped solution. The check valves must operate properly in order to assure performance of the pump. While chemical feeder manufacturers have gone to considerable length to design valving systems that will handle comparatively large amounts of dirt and particles, there is no point in asking for trouble by failing to keep solutions clean.

A pool operator may expect, as time goes by, to see scale developing in a chemical feed system. The rate at which this develops is affected by type of source, solution temperature, feed velocity, and the hardness of the solution makeup water.

It is wise practice to feed a dilute acid through the entire solution handling assembly of the chemical feeder periodically in order to dissolve such scale. This can be done simply by placing the solution intake point or foot valve in

a small reservoir of dilute muriatic acid or vinegar and operating the pump for a few minutes until the scale is dissolved.

Some chemical feed systems are furnished with timers or interrupter mechanisms to control their feed. The purpose of these is to operate the pump for a portion of the total filter cycle rather than continuously. This permits the chemical feed system to operate at a higher volume per unit time and thus assure greater volumetric efficiency. This is simply to say that it is possible to achieve greater accuracy in feeding at a rate of ten gallons per day than feeding at a rate such as one quart per day.

The technique of interrupted feed, in fact, makes it possible to feed hypochlorites at a maximum possible concentration, and reduce the frequency with which the solution reservoir must be refilled. On a 30,000 gallon pool, for instance, it is quite possible for one filling of a 50 gallon reservoir of sodium hypochlorite to last for two weeks or more. During all this time chlorine would be regularly fed without further attention. All swimming pool chemical feed equipment should incorporate a method for varying the output of the system. When residual tests are made, the output of the system should be changed, if necessary, to maintain the residual. After some experience, the skilled operator is able to anticipate need for change according to sum conditions, bather load, wind conditions and other factors that require more or less chlorine feed.

An important, but frequently neglected consideration is equipment service. Most manufacturers of swimming pool chemical feed equipment offer some arrangement for servicing their equipment through local offices, distributors or service companies.

Most swimming pools have at least a brief shutdown period during the year. Because of the nature of the chemical feed system and the fact that it is exposed to solutions which are corrosive, which may be highly acid or caustic and which may tend to form scale rapidly, it is important that the system receive at least an annual check as part of the pool maintenance routine.

With such an annual check, some modest care in maintaining clean solutions, periodic acid cleanouts to remove scale and conscientious output adjustments in response to residual tests, there is no reason why chemical feed equipment cannot make it possible for an operator to have a safe and sparkling clear pool at all times.

CHAPTER SIX

THE RECIRCULATION SYSTEM

It will assist one's understanding of the recirculation system to think
of it as a transportation system which keeps the water constantly in
motion. By means of a recirculation pump and piping, water is taken
from the pool, delivered to an equipment station where it is filtered
and chemically treated and then returned to the pool-carrying with it
a strong residual of chlorine for disinfection and oxidation purposes
as it re-enters the pool.

An imaginary ride on this transportation system (beginning in the pool)
provides a basis for discussing each of the devices and components(14)
encountered by the pool water as it recirculates. (See Figure 3)
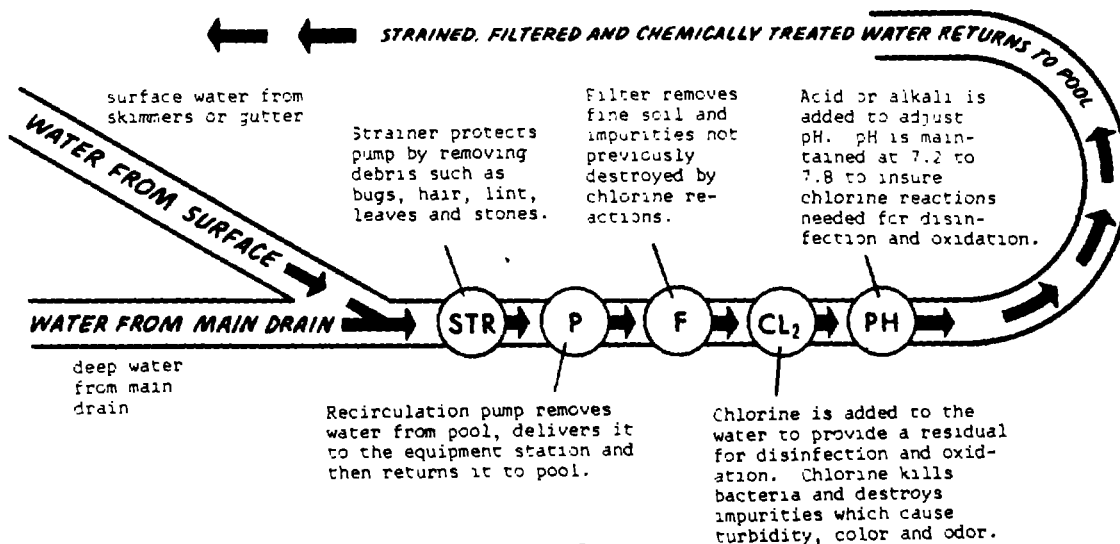
Figure 3

THE RECIRCULATION SYSTEM

> Note: Chlorine and/or pH feed may be provided upstream from
>   (ahead of) filter, especially is canses where sand filters
>   are employed.

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(14) There are several different types of recirculation system
design, each of which provides its own sequencing and placement of such
components as pump and filter, etc. Rather than identifying and
discussing each of these alternatives, it is believed the reader will
best be served by tracing flow through one typical system.

Drains, Overflow Gutters and Surface Skimmers

Water traditionally departs from the pool through each of two main routes:

1. Some is taken from the deepest point of the pool through the main drain. This enhances removal of heavier-than-water particles such as sand, silt, etc. Main drain removal also contributes ti mix-and-flow characteristics in the main body of pool water since the water which is constantly returning to the pool is commonly introduced at multiple inlets at the periphery.

2. Some water is taken from the surface of the pool by means of the overflow system consisting of overflow rims or skimmers or combinations thereof. Surface water removal is important since the top few inches are found to contain the highest degree of contamination due to oral and nasal discharges, airborne pollution, insects, etc.

Strainer

After leaving the pool, the water is delivered to an equipment area through a piping system which collects all water at a single point where it is strained through a sieve-like device often referred to as the "hair and lint strainer" or "leaf trap." At this point, a removable (for cleaning purposes) screen or basket collects leaves, hair, lint, gravel, insects and other relatively large particles which would otherwise clog at the pump impeller or other structures in the system. Such removal also reduces filter loading and generally improves overall system performance.

It should be noted in passing that clogging of the strainer is a progressive condition. As the strainer collects debris and becomes more and more "plugged," the flow of water from the pool to the recirculating pump is impeded. Severe accumulations in the strainer will "starve" the pump preventing sufficient water from reaching it. This will cause a condition known as "cavitation"(15) resulting in noise, vibration and erratic performance in

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(15) Cavitation occurs when blockage or restrictions in the suction piping cause the pump to labor to obtain water. The typical recirculation pump is designed to withstand the work of pushing water downstream from its impeller, but it has a much lower resistance to damage when pulling water to its impeller. Cavitation is evidenced by a high vacuum gauge reading at pump suction, and by knocking and grinding sounds. The sounds are condensation of vapor bubbles formed in the water by the high vacuum on the suction side as they pass through the pump into the pressure side.

the pump. Prolonged cavitation will result in serious damage to the pump impeller, bearings and seal.

Filter Plant

Having been strained of its large chunk-like impurities, the water is then delivered to the filter plant where the process of fine-particle removal is accomplished. It is at this point that the chemical disinfection and oxidation processes (which beneficially take place after the water again reaches the pool) are aided by the removal of very small soil particles such as dust, body oils, algae, slime, bacteria, coagulated material, etc.

The undersirable materials may be removed in any of several mechanical systems which are the subject of discussion in the remaining chapters. In the present state of the art, pool filtration is achieved most commonly by particle entrapment in either (1) a bed of sand, or (2) a thin cake of diatomaceous earth.

Chemical Feeders

As the pool water continues its journey beyond the filters it is chemically treated for the many reasons discussed in prior chapters. (16) Chlorine disinfecting agent is added, pH adjustment chemicals are introduced, and the water is returned to the pool ready to destroy bacteria and oxidize other undesirable solids.

Inlet Distribution System

The manner of re-entry is governed by the location and sizing of inlets. When a swimming pool is in its design stage prior to construction, great care is exercised to locate and size the inlets to obtain the best possible flow characteristics of the filtered and treated water. The inlet fittings themselves are normally adjustable to provide for control of volume, velocity and even direction to obtain overall system balance. The object, of course, is to provide rapid and uniform dispersion of treated water.

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(16) In one typical system the chemical treatment of pool water takes place <u>after</u> filtration. Other systems might well provide for chemical treatment <u>before</u> the water reaches the filter plant. For example, in sand filtration it is quite common to introduce chlorine ahead of the filter battery.

Calculation of Turnover

As noted in Chapter One, the recirculation of a swimming pool is based
upon turnover, or the rate at which the entire volume of the pool is
theoretically recirculated through the equipment station. Initially
pool turnover is the responsibility of the designer who must insure
that the mechanical system is of a sufficient capacity to handle the
desired flow. As a practical matter, however, it is also desirable for
the pool operator to know how the design rate is determined, for he
will occasionally be called upon to make system evaluations which
require such knowledge. Since most public pools are required to be
operated at a turnover rate of six to eight hours, the operator should
understand the arithmetic for computing pool volume and
should be able to translate his findings in terms of flow rates.

The approximate volume of a given pool is calculated by multiplying pool
length (in feet) by pool width (in feet) by average pool depth (in feet)
by 7.5(17) as illustrated in Example 1.

Example 1

A swimming pool 50 ft. long by 20 ft. wide sloping uniformly from 3 ft.
depth at shallow end to 8 ft. depth at deep end.

       Area of pool (50 x 20) equals 1,000 sq. ft.

       Averae depth $\dfrac{8 + 3}{2}$ equals 5.5 ft.

       Volume of pool (1,000 x 5.5) equals 5,500 cu. ft.
       Capacity of pool (5,500 cu. ft. x 7.5 gal. per cu. ft.)
       equals 41,250 gallons

The calculations of Example 1 make it possible to determine the pumping
rate required to provide an 8 hour turnover as shown in Example 2.

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     (17) Length times width times average depth expresses pool volume
in cubic feet. Since one cubic foot of water contains 7.5 gallons,
the multiplier 7.5 times pool volume in cubic feet expresses total
gallonage.

Example 2

        Volume of pool in gallons equals 41,240

        Volume (41,250) divided by turnover time (8) equals
        5,156 gallons per hour

        Gallons per hour (5,156) divided by minutes by minutes (60)
equals pumping rate of 85.9 GPM (gallons per minute) An individual
responsible for the operation of the pool illustrated should, by
reference to flow meters and manipulating of valves, maintain a constant
flow rate of 85 GPM plus or minus 10%. (18) Such operations will provide
a turnover rate consistent with good pool management practice. Since
rate of flow is constantly being affected by soil accumulation in
strainer and filters, it is necessary for the operator to understand
the function to these mechanical components in order to keep the
overall recirculatiion system functioning efficiently. It is the
object of the final chapter of this manual to provide such
knowledge.

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        (18) The public pool is equipped with a rate-of-flow indicator
which provides a quick visual reading to flow rate at some convenient
point in the equipment area. The experienced pool operator also
learns to interpret rate-of-flow from pressure and vacuum gauge
readings.

CHAPTER SEVEN

FILTRATION - GENERAL

It may seem entirely too elementary to discuss the purpose of filtering pool water. However, there are many who confuse the filtration function with the disinfection function, and it is therefore desirable to distinguish between the two and place each in its proper perspective.

Disinfection is the chemical process of killing disease-causing bacteria as well as other types of micro-organisms. In a pool this is accomplished in only one way: By maintaining, in the body of pool water itself, a uniformly dispersed residual of some chemical (usually chlorine) capable of killing bacteria.

Filtration is the physical process of removing dirt particles and solids which, if not so removed, would interfere with and impede the disinfection process. (19) Those who think of filtration as a disinfection process because filtration is capable of removing some bacteria are dangerously misled insofar as swimming pool technology is concerned.

While filtration does remove some bacteria this is not its purpose, nor is such removal particularly beneficial. Rather, the primary purpose of the pool filter is to remove all manner of foreign particles which would otherwise increase the chlorine demand of the water, thus lowering chlorine residuals and weakening the killing power of those chemicals which have been added for the purpose of sterilizing the water.

To accomplish this purpose of particle removal through filtration, there are many alternatives open to designers and builders.

Two primary filter types will be considered, sand (or permanent media) and diatomite, starting with the premise that both systems are equally efficient and acceptable.

Both sand and diatomaceous earth filters, assuming they are of good design, deliver effluents of equal quality. It is little more than an intellectual exercise to debate which of the two will remove the smaller particles in terms of micron size.

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        (19) The purpose of such soil removal, as discussed in foregoing chapters, is to aid chemical disinfection and oxidation.

The Recirculation Pump

The typical swimming pool recirculation pump is a centrifugal pump
which, as the term implies, imparts energy to the water generally by
centrifugal force. Water is drawn to the eye of an impeller and then
thrown from the outer perimeter of the whirling impeller into a volute
or chamber which encloses the impeller. From the volute the water is
driven under pressure into the piping system. If the water has been
filtered prior to reaching the pump, it is sent from the pump discharge
directly back to the pool. If the water has not yet been filtered when
it leaves the pump discharge, it is sent first to the filter station
and then on to the pool.

If the water is filtered before reaching the pump (at the suction
side of the pump), the filter system may be either a vacuum or gravity
system. If the water is filtered after reaching the pump, the system
is described as a pressure system since the water is then normally
delivered to the filters under pressure. Regardless of which system
is employed, the hydraulic conditions encountered are much the same.
For the sake of clarification, however, the discussion is made more
understandable by dealing with one of the two systems. Since the
pressure system is by far the more common of the two, it is chosen for
example in the ensuing discussion.

The characteristics of a given recirculation pump are described by its
performance curve. This performance curve can best be understood by
imagining two sets of conditions. The typical pump performance curve is
expressed graphically by means of a chart which illustrates how much
water a given pump will deliver at each of several different conditions
of resistance. The amount of resistance is expressed in pounds per
square inch or feet of head at the vertical line of the chart to the
left in the accompanying illustration. (20) (See Figure 4)

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        (20) Resistance to flow (often referred to as "head loss" or
"friction loss") is measured in terms of pounds per square inch or
feet of head. In this pump curve (illustration) the resistance is
expressed as feet of head.

TOTAL FLOW
Expressed in gallons per minute (GPM)
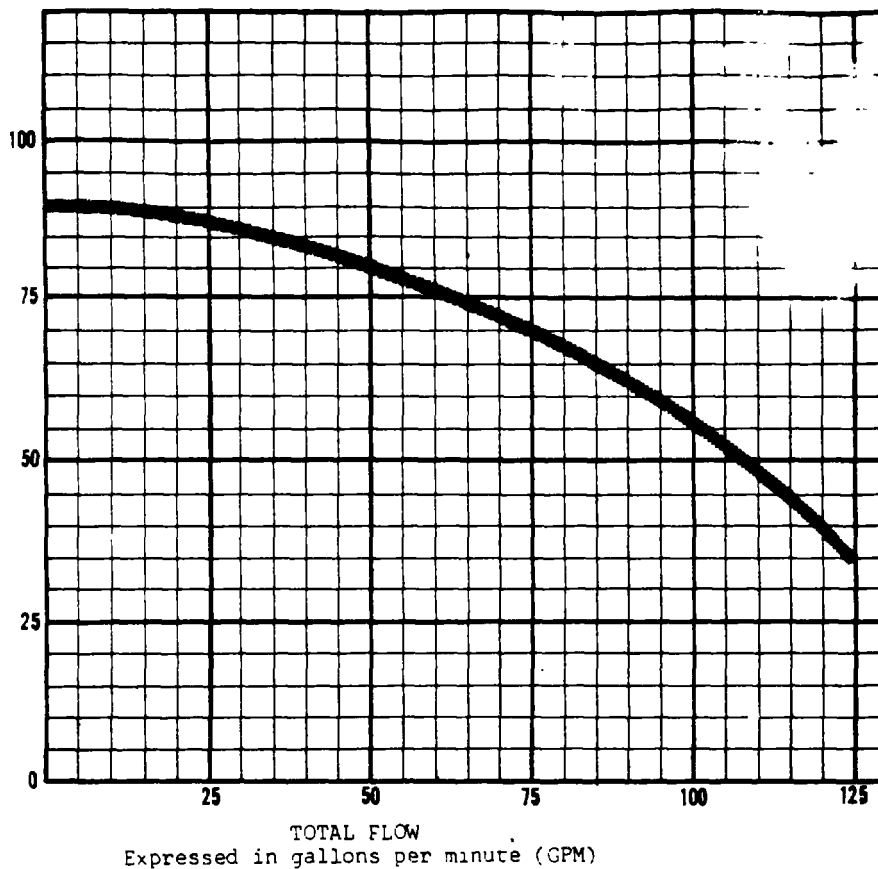
Typical curve of 2 H.P. swimming pool pump   Figure A

TOTAL RESISTANCE TO FLOW

The amount of flow is expressed in gallons per minute (GPM) at the hori-
zontal base line of the chart. This pump curve chart is chosen since it
describes a pump which a designer might well choose to recirculate
the 41,000 gallon pool used for illustration in Chapter Six,
Calculation of Turnover.

The desired 85 GPM would be delivered by this pump when it is pumping
against a total system resistance of 67 ft. of head. When resistance
to flow is only 35 ft. of head, this same pump will deliver 125 GPM.
But if resistance increases to 80 ft. of head the pump will deliver
only 50 GPM, and at 90 ft. of head the pump will cease moving water
altogether.

As the soil removal process takes place in the filter medium, the dirt
accumulation increases resistance to flow and eventually flow is reduced
below the specified amount and the filter must be cleaned. Conversely,
when the filter is cleaned and returned to service, resistance to flow
is at its

minimum and flow is at its maximum. Thus it can be seen that the
swimming pool pump output varies constantly from beginning to end of
the filter cycle.

It is important here to note that it is undesirable to vary greatly in
either direction from the desired flow rate for a given pool. As
filter clogging increases resistance, reduction of filtration rate is
obviously undesirable. At the other extreme, flow well above the
designed filtration rate may shorten filter cycles.

As a practical matter the swimming pool pump is chosen by the designer
by totaling all of the resistances to flow which will be encountered
in the circulation system and adding the resistance which will be
encountered due to soil accumulation during the filter cycle. The sum
of these resistances enables the designer to select a pump which will
deliver the desired flow against all of the controllable conditions
which are expected to be encountered in a properly operated system. It
then becomes the operator's responsibility to carry out the intent of
the designer. At the outset of the filter cycle the operator must
adjust the flow control valve to artificially impart the resis-
tance needed to protect the system against too high a flow (21). As the
cycle progresses the operator must continue to adjust the control valve
to keep the flow "centered" at its desired setting. When the point is
finally reached at which no further adjustments will maintain adequate
flow (due to dirt accumulation in the filter), the filter must be
cleaned and restarted on a new cycle. All throttling of the
recirculation pump should be done on the DISCHARGE side of the pump -
never on the suction side.

Filter Types

There are five different filter types which are traditionally
acceptable:

(1) pressure sand, (2) pressure diatomaceous earth and (3)
vacuum diatomaceous earth, (4) gravity sand, and (5)
cartridge filters. The first 3 types are predominantly in use
today.

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        (21) In recently designed systems it has become common practice
to install devices which automatically control flow up to the point at
which filters no longer need compensating control since the head loss
is provided by dirt loading. In such systems the operator does not
need to manually throttle flow in the early stages of the filter cycle.

From the viewpoint of dirt removal efficiency, the three systems can be said to be relatively equal. However, since each of these systems possesses its own unique characteristics with respect to operation procedure and hydraulic response to dirt loading, each must be discussed separately. For purposes of discussion these filter types are divided into two general categories:

(1) permanent media filters (predominantly sand, although anthracite is sometimes used) in which the filter medium remains in the filter after the soil load is backwashed to a waste disposal area or sewer, and

(2) disposable media filters (predominantly diatomaceous earth) in which the filtering medium and the accumulated soil are disposed of together. A new supply of the filter medium is deposited in the filter for each cycle.

> Note: Volcanic ash and specially processed pumice are
>   sometimes employed as filter aids in place of
>   diatomaceous earth.

SAND FILTRATION

Theory and Mechanics of Soil Entrapment

Of the two commonly used pool filter systems, the sand system is the easiest to understand. Soil is captured in the filter bed by a combination of two processes: (1) gelatinous and mucous-like substances and oils tend to cling to the grains of filter said, and (2) solid particles lodge in the extremely small spaces and voids between the sand particles. As these two dirt collecting mechanisms work together, the filter bed stores up more and more dirt and becomes increasingly dense and resistant to water flow. Ultimately adequate flow can no longer be sustained and it must be cleaned by backwashing.

The accumulation of the gelatinous and mucous-like substances referred to above is a dirt retention function which is often described as flocculation. A sand bed does not become efficient as a filter until there is a sufficient accumulation of floc (fine soil) to inhibit the passage of very small solids. As a result the sand filter does not normally attain its desired efficiency until after it has operated for a period of 8 to 16 hours.

The formation of floc (filter efficiency) can be accelerated by adding aluminum sulphate or potassium alum to the recirculation stream ahead of the filter at the outset of the cycle. This practice is not nearly as widespread as it once was, however, since such flocculation materials are not effective except at high pH. Since it has been observed that high pH of swimming pool water is not desirable (22) for reasons relating to disinfection and oxidation, many operators reject the practice. Since the filter bed will floc itself in due time, it is reasonsed to be acceptable practice to sacrifice the first few hours of efficiency in return for the longer filter cycles which are obtained by letting the floc develop from soil in the pool.
It is important to note that the dirt holding characteristics of a sand filter are also importantly affected by the chemical treatment of the pool water. Good chlorination practice burns up many of the unwanted materials which would

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        (22) For a discussion of the effect of high pH upon chlorine reactions, see Appendix B.

otherwise collect in the filter bed. Chlorination also breaks down
soil barriers already accumulated in the filter medium, (23) thus
reopening clogged spaces and passages making them once again free to
collect soil.

Finely crushed hard coal (anthracite) can be used as a filter medium
in the same manner as sand is used. It functions in the same way but
is back-washed at lower velocities to prevent washing the medium to
waste with the backwash water during the cleaning cycle.

Physical Plant

There are two types of pressure sand filters commonly used in swimming
pools today and a third type, referred to as gravity sand which is
occasionally employed. The commonly employed pressure systems are
referred to as rapid sand, which is the tradional system developed
many years ago, and high rate sand, which is relatively
recent technology. The three systems vary significantly and are
therefore separated for discussion.

Rapid Sand

The typical rapid sand public pool filter is a round steel vessel
approximately five feet in height loaded with 24-inch deep bed of sand
supported on four layers of gravel graded to uniform size (see Figure
5). The stratified gravel bed performs two functions in the sand
filter:

1. It serves as a barrier which prevents the sand from washing
    through the underdrain into the pool during the filter cycle,
    and

2. It serves to distribute the flow of water uniformly to the
    underside of the sand bed during the backwash cycle.

The size of the sand particles which serve as the filter bed is an
important consideration. If the sand is too coarse, the voids between
the particles are too large to efficiently stop the passage of fine
solids. If the sand is too fine, the sand bed will be too dense so
that very little space is left for dirt to accumulate between the sand
grains. The ideal filter sand particle size has been established in a
range of 0.4 to 0.6 millimeters.

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    (23) This phenomenon probably accounts for the traditional
practice of introducing chlorine into the recirculation system ahead
of (upstream from) sand filters. There is good reason to believe that
the chlorine-rich water entering the sand filters tends to produce a
re-opening effect in the filter bed. By burning out already
trapped material, new dirt holding capacity is restored
and the cycle is prolonged.

UNFILTERED WATER FROM POOL

BAFFLE

SAND

FINE GRAVEL
MEDIUM GRAVEL
COARSE

FILTERED WATER

GRAVEL
CONCRETE

UNDERDRAIN

Typical pressure sand filter - as water flows downward
through filter medium, soil is collected in the sand bed
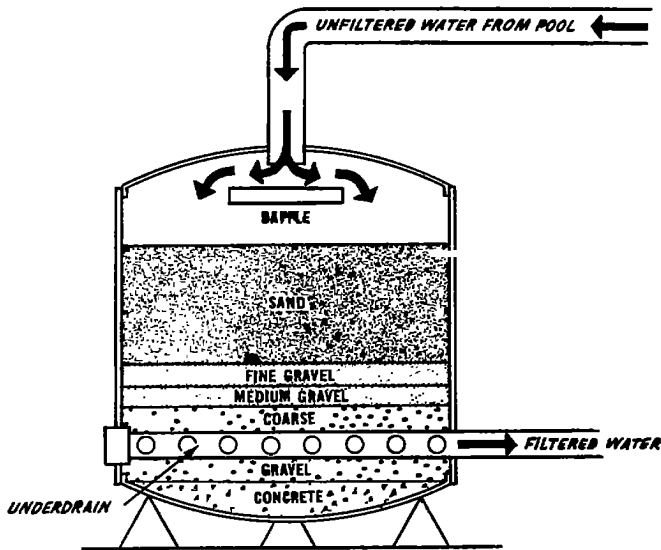
Figure 5

Typical pressure sand filter - as water flows downward
through filter medium, soil is collected in the sand bed.
A splash plate is positioned above the sand bed to baffle the incoming
water and prevent impingement of the stream directly upon the filter
bed. A perforated pipe or dome-like underdrain is placed in the
bottom layer of the coarse gravel to collect the filtered water and
return it to the recirculation system piping.

The space in the filter vessel above the filter bed is referred to as
"free-board" area, and is necessary to allow for expansion of the sand
bed during backwash procedure.

Typically, the sand filter system on larger public pools is a battery
of 2, 3 or 4 individual tanks (24) manifolded together in order to
receive relatively equal portions of the total flow during the filter
cycle. This multiple cell

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        (24) Or a single horizonal tank partitioned to contain 3 or 4
separate cells or compartments.

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arrangement provides a very important accommodation to the backwash cycle. Since the sand filter must be backwashed at approximately 4 times the rate used during the filter cycle, the recirculation pump can provide the necessary backwash velocity only if the filter cells are backwashed one at a time. If the sand filter were a single vessel, a separate pump much larger than the one used for recirculation would be required for efficient backwash.

Flow Rates and Filter Sizing

The diameter of the filter vessel is governed by the size of the pool to be filtered, and is specifically determined by reference to flow rate per square foot of surface area of the sand bed. Since sand was first used as a filter in the processing of public drinking water supplies, the technology of sand filtration was quite naturally developed by public health agencies and the water works industry. During this stage of development it became traditional to filter water at a rate of three gallons per minute per square foot of sand bed surface area. (25) Thus if a given system required a total flow of 600 gallons per minute (GPM), a filter system containing 200 square feet of sand surface area was provided.
Since the flow rate traditions were established by public health agencies which were also concerned with public swimming pool water filtration, it was quite natural that these traditions were carried over into the swimming pool field. Today it is still common practice to use 3 GPM/sq. ft. as a standard of design and operation of public pool sand filters. (26)

Thus, using the example cited above, a swimming pool containing 216,000 gallons of water, recirculated at a turnover rate of six hours would require a system filtration rate of 600 GPM. The 3 GPM/sq. ft. filter flow rate establishes the filter size at a total needed area of 200 sq. ft. Since a standard 96-inch diameter sand filter tank provides 50.3 sq. ft. of cross sectional area, a four tank battery of 96-inch diameter filter vessels would exactly provide the needed sand surface area.

Carrying the example one step further, by backwashing the filter cells individually at the full circulation rate of 600 GPM, each filter bed would receive a flow four times the rate it experiences during the filter cycle or

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(25) The pool water clarity obtained at this filtration rate has usually been considered acceptable by public health officials.

(26) Recent developments in the swimming pool industry suggest that sand filters might be successfully operated at flow rates substantially in excess of 3 GPM/sq. ft.

12 GPM/sq. ft., the approximate rate needed for effective cleaning and for satisfying public health agency requirements. (27)

High Rate Sand

The typical high rate sand filter is normally a round pressure vessel with a special influent baffle in the top of the tank, a bed of filter sand and a mechanical underdrain system to collect the filtered water and direct it to the return piping system. The underdrain is often of a design which serves as a barrier to the migration of the sand bed, and as a backwash water distributor without the requirement of the stratified gravel bed which was traditionally used in the rapid sand systems.

The high rate system differs from the rapid sand filter substantially in its total plant size and hydraulic characteristics. Instead of operating at the traditional flow rates of 3 GPM per sq. ft. of filter surface area, it is operated at flow rates of from 15 to 25 GPM per sq. ft. of filter surface area. Since the total flow requirements of a given pool can thus be satisfied through a sand bed of considerably smaller surface area than in the case of rapid sand systems, the physical plant of the high rate filter is much smaller as well. It is therefore possible, for example, to adequately filter a 90,000 gallon pool through a single high rate filter tank 48 inches in diameter whereas a rapid sane system for the same pool would require the use of a battery of three filter tanks 72 inches each, in diameter. Although a rather dramatic departure from the design and function of the rapid sand filter, the high rate system provides an effluent of excellent quality. This seems largely due to its increased dirt holding capacity.

The high flow rate drives the dirt load deeper into the filter bed, thus increasing the dirt holding capacity of the medium. In the typical rapid sand system the primary soil load is confined to the top 2 to 4 inches of the sand bed, whereas the high rate filter collects soil down through the entire depth of the sand bed.
The high rate filter system is normally backwashed at or near its filter flow rate of 15 to 25 GPM/sq. ft.

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(27) Many public health agencies require a sand filter backwash rate of 15 GPM/sq. ft. Where the same pump is used for both filtration and backwash in single tank filter systems, special attention must be paid that the pump is capable of this flow at sufficient head to overcome system losses. Many times the backwash rate is a more critical selection for the pump than the filter rate.

The Gravity Sand System

The gravity sand system was commonly used in the early history of public
pool design but has been largely outdated by the pressure system which
can be installed and operated in a much smaller area. Although the
sand bed functions as a filter medium in the same manner in both
systems, the gravity plant occupies many times the ground space
required for its equivalent pressure plant. Also, the backwashing
procedure requires both more manual labor and much more wastage of
water.

The Backwash Cycle

Since the filtration of water is accomplished by directing the water
downward through the filter bed, it is quite natural to expect that the
system is cleaned by reversing the flow and causing the water to course
upward through the bed. The action of the backwash water tends to
slightly expand the bed and the sand particles tremble and scrub
against each other, causing the collected soil to break free (28)
and wash out of the filter vessel to a point of disposal. In rapid
sand filter systems the backwash cycle is normally continued until
the backwash effluent is observed to be free of soil, a period of about
8 to 10 minutes per cell. In high rate filters backwash is
accomplished in about 2 minutes because of the greater velocity of the
backwash water.

Backwashing the high rate filter is extremely simple because there is
generally only one tank in the system. However, in order for the
operator to fully comprehend the backwash function in the older rapid
sand systems, several important observations should be made.
The nature of the foreign material which accumulates in a swimming pool
filter causes clumping of the soil to some extent. With hair or lint
often serving as a structure, balls of organic material (29) will
form and become imbedded in the top layer of sand. If backwash
velocities are insufficient to wash the clumps to waste, they will
work their way deeper into the filter bed creating channels which
ultimately permit unfiltered water to take a path of least
resistance through the medium.

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      (28) If one could physically handle the medium during backwash,
one would find the entire sand bed lightly suspended and slightly in
motion. One could easily thrust his arm through the bed and down to
the underlying bed of gravel.

      (29) In swimming pool parlance these are called "mudballs."

Another undesirable result of insufficient backwash velocities is termed calcification. If the bed is not sufficiently disturbed to expand slightly, it may eventually become encrusted with a cement-like mass and will become impervious to the flow of water. This phenomenon is particularly likely to occur if pH and total alkalinity of the pool water (30) are permitted to become unreasonably high.

While inadequate backwash velocity is undesirable, so is a backwash rate which substantially exceeds 15 GPM/sq. ft. In some circumstances the full capacity of the recirculation pump will cause the sand and gravel bed to tumble and partially invert the sand layer and the layer of small gravel immediately beneath it. If this condition occurs, channeling can take place similar to that caused by the mudballing described above. The condition can be corrected only by removing and reloading the first two strata of media.

For the reasons presented it can be seen that the backwashing of the rapid sand filter system involves much more than a mere reversal of flow. The operator must establish the backwash flow rate with care to avoid the problems which result from either inadequate or excessive flow rates.

Regardless of the care taken to protect the bed, the rapid sand filter should be periodically opened and inspection made of the bed. If signs of mudballing or calcification are observed, steps should be taken to correct the problem by soaking the bed with corrective chemicals such as acids and detergents.

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(30) For discussion of control of pH and total alkalinity, see Chapter 2 entitled CHEMISTRY OF CHLORINATION.

CHAPTER NINE

DIATOMACEOUS EARTH FILTRATION

A filter type commonly used for filtering swimming pool water makes use of a dirt collecting medium which is discarded along with the dirt itself when the filter cycle is completed. There are three or four disposable media which can be used in such systems but the one used most commonly is diatomaceous earth. (31) It is therefore adopted as a term of reference to describe such filters throughout this chapter.

To the naked eye diatomaceous earth is a fine white powder, but under the microscope it is seen to possess certain unique properties which make it highly desirable as a filter medium. As an individual particle, it exists in many shapes, all of which might be said to resemble a petrified tumbleweed of near microscopic size. It resembles the tumbleweed because it is a lacy, web-like particle which is approximately 90% void and 10% solid fiber. It is petrified in a literal sense since it is the rigid, skeleton-like fossil of a very small form of plant life which lived in prehistoric times.

The characteristics which make diatomite a filter medium can thus be seen when one imagines a cake or crust of these particles being placed in the path of a flowing stream of water (see Figure 6). Such a filter medium is literally a structure of small, rigid, porous particles piled one upon the other to form a fine screen. The openings in the screen are sufficient in size to permit the flow of water, but are so small as to obstruct the passage of virtually the smallest particle of foreign material which the water may contain.

Even droplets of viscous, oil-like liquids will be caught up in the web. The DE filter cake is therefore a highly efficient filter medium, so efficient in fact, that it requires very special care to keep it porous and functioning for extended periods of time.

The Filter Septum

All diatomaceous earth filters are equipped with septums (often referred to as the filter elements) or devices upon which the DE powder is collected in

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(31) Diatomaceous earth becomes a clumsy term when it must be repeated frequently in discussion or text. It is therefore common practice to abbreviate the term by using the initials DE or the abbreviated form diato-mite.

FILTER FABRIC

FILTER CAKE

DIATOMITE PARTICLES

SOIL PARTICLES

In a typical diatomaceous earth filter,
a thin cake of diatomite is collected
upon a screen or fabric which is
supported by a septum. Soil particles
are collected in the filter cake.

Filter cake may be kept porous longer
by continuous feed (body feeding) of
diatomaceous earth.
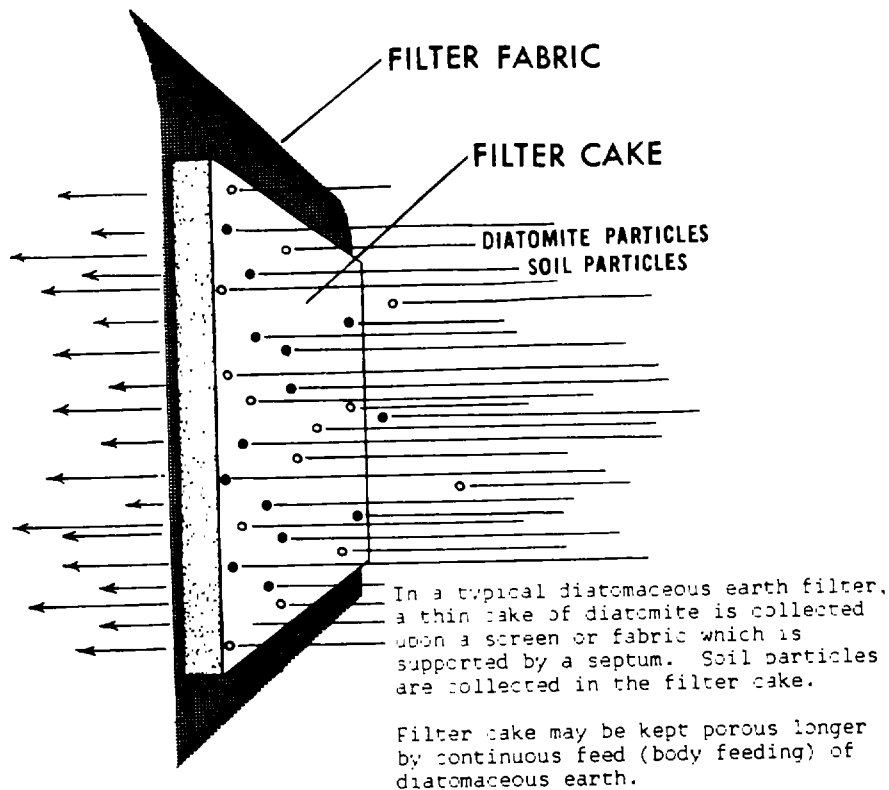
FILTER FABRIC

its cake form. The septum may be a cylindrical tube or a wafer-like structure covered with a plastic or metal fabric of sufficiently fine weave to collect the filter cake. (32) The septum is often a bundle of tubes, discs or wafers assembled to a pipe or pipe-manifold which receives the filtered water and directs it on to the pool through the recirculation system piping.

Precoating the Filter Septum

The act of depositing the filter cake upon the septum is called "precoating." It involves mixing a slurry of diatomaceous earth and water, and then introducing the mixture at a point in the recirculation system which will result in

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(32) In its commercial form diatomaceous earth filter powder contains a small percentage of extra large DE particles which collect on the porous septum fabric forming a bridge to support the filter cake which is comprised mostly of much finer particles. When the original filter cake is being formed the DE slurry is usually recirculated through the septum until all of the particles are finally deposited in position to serve as a filter medium.

the slurry eventually being deposited upon the septum. (33)

The precoat slurry is prepared in accord with a formula which provides for a precoat cake thickness of 1/16 of an inch minimum. (34) This is accomplished by preparing a slurry which contains 1/10 lb. of diatomite powder for each square foot of septum surface area to be coated. (As a practical matter it is good practice to mix a slurry containing 1-1/2 lbs. of DE powder for each 10 square feet of septum surface area because some of the slurry will pass through the septum and be deposited in the pool or delivered to waste during the initial precoating of the septum.) It is not really an objectionable practice to deposit a precoat thicker than 1/16 inch, but a pre-coat of inadequate thickness can be a serious operational error. Such a failure will not only reduce filtration efficiency, it will also leave the septum fabric unprotected and exposed to direct soil accumulation. If the septum fabric itself becomes soiled with sticky organic material, it will not properly release its soiled filter cake during the cleaning (backwashing) cycle. As a result the septum(35) itself will become clogged with unreleased filter cake, the available filter surface area will be reduced, and the filter will become short-cycled and inefficient.

Continuous Body Feeding the DE Filter

If the operator truly understands the function of diatomaceous earth as a filter medium, he will then understand why a single precoat of a filter septum will

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   (33) The point at which the precoat slurry is introduced to the flowing stream of water must obviously be ahead of (upstream from) the filter. It is normally mixed in a precoat pot connected to the filter or to the piping which leads to the filter. (In an open vacuum type DE filter the powder may be sifted dry directly into the filter vessel.) By gravity, or other means, the slurry is conveyed to the filter and recirculated through the septum until it has established a satisfactory filter cake.

   (34) Such a thin filter cake seems incongruous to the novice operator until he understands that particle removal in diatomite filtration takes place at the surface of the filter powder coating. Once the crust is formed its surface becomes a filter membrane and its depth is of no real consequence.

   (35) The true meaning of the term septum means to separate-in filtration terminology meaning to separate the soil laden filter cake from the element which supports it. If the filter element is kept clean and unsoiled by its protective layer of diatomaceous earth, the dirt load will be efficiently released from the septum when the cleaning or backwashing cycle is started.

not long keep a given filter functioning. Since the soil is filtered out at the surface of the filter cake, the cake is soon slimed over and clogged with solids which inhibit flow. Such a condition would produce very short filter cycles and make the DE system objectionable for this reason alone.

In the practice of DE filtration it is possible to keep the filter cake porous and increase its dirt holding capacity by continuing to feed filter aid (diatomaceous earth) into the system through the process known as body feeding or slurry feeding. This involves the rather simple practice of introducing a continuous feed of DE filter powder into the unfiltered stream of pool water as it approaches the filter system. By mixing porous filter aid particles into the stream of soiled water, the filter cake receives a mixture of particles, some of which are dirt solids, and some of which are porous DE particles which actually add new dirt collecting and dirt holding capacity.

The practice of body feeding causes the filter cake to swell and thicken, but it increases its capacity to receive and store up soil in the process, so the filter cycle is extended far beyond what would be provided if body feeding were not practiced.

In the realistic, non-theoretical environment of the public pool, the slurry feeding technique becomes a variable control which the operator uses in a highly discretionary manner. If bathing loads are heavy, with resultant heavy dirt accumulation, the operator should increase the rate of body feed. As bathing loads subside the experienced operator will continue the heavy feed for a time, until the heavy soil accumulation has been largely picked up in the filter. He will then reduce the rate of feed until the need for heavy feeding is again presented. Body feeding, like chlorine feeding, is measured against demand and the rates are adjusted accordingly.

The Physical Plant

Once the filter medium and septum are well understood, the diatomaceous earth filter plant is rather easy to visualize. It may be either a closed vessel which operates under pressure, or it may be an open tank from which the water is drawn under vacuum to pump suction. In either case the system is comprised of a tank to receive unfiltered water from the pool, a septum to support the filter cake, and a pipe or manifold to collect filtered water from the septum and deliver it to the distribution system piping. In the case of the pressure type system, a crock or tank for precoating the filter is attached either to the filter itself or to the adjacent piping. There are many shapes, sizes and design configurations since there is a great deal of latitude with respect to septum design and collector piping arrangements.

There are two commonly used types of body feeding equipment. The vacuum

DE filter is sometimes equipped with a "dry" feeder consisting of a hopper containing the diatomite charge positioned over the filter cell. A vibrator or other device may be used to deposit measured amounts of diatomaceous earth directly into the filter.

The more common system employs equipment which feeds the filter powder as a slurry. The slurry feeder normally is made up of a tank containing a mixture of diatomite and water, a motor driven agitator or propeller to keep the diatomite in suspension, (36) and a metering pump which draws the slurry from the tank and pumps it to the unfiltered water stream ahead of the filter. A relatively dilute slurry is desirable since the diatomaceous earth particles have a tendency to settle and pack or clog at points of low velocity in the pump, fittings and solution tubing. A ratio of one-half pound of diatomite per gallon of water is probably ideal, but the ratio is not at all critical and much heavier slurries can be handled if the operator keeps the equipment functioning properly. Regardless of the ratio of diatomite to water, the slurry feed charge should be prepared daily, if possible, or at least every other day. The DE particle is very brittle and prolonged agitation in the slurry tank will tend to fracture the particles and greatly reduce their efficiency as a filter medium.

Flow Rates and Filter Sizing

As in the case of the sand filter, the size of the diatomaceous earth filter is governed by the size of the pool to be filtered. However, since DE filtration is relatively new technology, we do not have an inherited flow rate to serve as a guide in sizing the filter system. Instead, the optimum flow rates have had to be learned from experience in the laboratory and in the field.

Experience has taught that the filter flow rate is far more critical in the operation of the DE filter than in the operation of the sand system. It was noted that flow rates can apparently be substantially increased in sand filtration without materially affecting cycles. The diatomite filter, however, gives markedly reduced filter runs as the flow rate is increased. Having learned this it has become common practice to provide DE systems of sufficient size that they can be operated at filter flow rates of from 1 to 2 gallons

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    (36) Diatomaceous earth is a particle of relatively high specific gravity and will therefore rather quickly settle out of suspension. The water in the slurry feed tank must therefore be kept in motion in some manner in order to keep the DE particles suspended and flowing through the feeder.

per minute (GPM) per square foot of filter surface area.(37)

Using the example cited in the foregoing chapter, a 216,000 gallon pool operating at a six hour turnover would require a system flow rate of 600 GPM. At a 2 GPM/sq. ft. filter flow rate the system would be provided with a filter having 300 sq. ft. of septum surface area. At a one gallon rate the filter would provide 600 sq. ft. of septum area. The 600 sq. ft. filter has twice the dirt holding capacity of the 300 sq. ft. filter and therefore is obviously the best choice of the two. Since the diatomaceous earth filter lends well to compactness of design and large dirt holding capacity in a relatively small space, the logic is profoundly in favor of low flow rate systems when diatomite filters are used.

Cleaning the Diatomite Filter

The diatomaceous earth filter responds hydraulically to dirt loading in the same manner as the sand filter. As the medium becomes clogged with soil it offers increasing resistance to the flow of water and eventually it must be cleaned and recharged with filter powder. The manner in which the filter is to be cleaned has been largely predetermined by the manufacturer of the equipment and there is little reason to discuss the various mechanical systerms and procedures which are offered commercially. It is worthwhile, however, to examine the basic differences between the vacuum and pressure type systems.

The typical vacuum filter is an open tank. As the recirculation pump draws the water through the septum the dirt loading and build up of the filter cake can be visually observed by the pool operator. When the vacuum gauge and flow meter readings indicate that the filter should be cleaned, the pump is stopped, the filter cell is drained down and the elements are manually washed down with the high velocity stream from a garden hose. It is possible for the operator to make certain that he has effectively removed all of the soiled cake from the filter elements before returning the filter to service.

The pressure diatomite filter is normally a tightly sealed vessel which cannot be readily opened to expose the elements to manual cleaning. Instead, the system is provided with one or a combination of devices and procedures for reversing the flow of water through the septum, to jet spray the elements, or to flex or move the elements within the vessel to assist in releasing the soiled cake, etc. Also, frequently the pressure filter is equipped with visual

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    (37) When operated at such low flow rates, together with body feed, it is not uncommon for the diatomite filter to provide filter cycles of two, four or even six weeks.

inspection ports to assist the operator in appraising the efficiency of the cleaning operation.

The best cleaning systems and techniques, however, will not prevent the eventual accumulation of some soil in the septum fabric and the loss of some filtration efficiency. For this reason it is good practice to periodically open the filter vessel and clean the septum manually.

NATIONAL SWIMMING POOL INSTITUTE

SUGGESTED MINIMUM STANDARD
for
PUBLIC SWIMMING POOLS

        Since its inception in 1956, the National Swimming Pool
Institute has, in the public interest, devoted itself to both the
technical and nontechnical areas of the swimming pool industry. It
has developed industry standards and codes for pool construction and
equipment, raised the industry's standards of business practices,
expanded the public's interest in swimming, encouraged national
participation in competitive swimming, published manuals and
conducted clinics on pool operations and has been a general
information source on residential and public swimming pools.

        Today, supported by a membership of more than 1,500 swimming
pool builders, maintenance firms, distributors and manufacturers of
swimming pool products, the National Swimming Pool Institute has
integrated its technical activities on matters affecting the public
health and safety with federal agencies and other representative
national organizations such as the Public Health Service, the
American Red Cross, National Sanitation Foundation, the American
Public Health Association, the "Y" groups, the Council for National
Cooperation in Aquatics, National Safety Council, Underwriters
Laboratories, the National Fire Prevention Association (National
Electric Code), and building and materials trade associations.

        The attached standards document, as revised in 1969, represents
three years of study by the Institute's Standards and Codes Committee
and the coordination of the Technical Council. Henceforth, this
standard will be reviewed on an annual basis. It is hoped that it
will provide a major reference for all state, county and municipal
officials, civic organizations and communities and pool operators
everywhere with the latest technology and concepts in swimming pool
construction and/or operation.

DEFINITIONS

For purposes of these standards, a RESIDENTIAL POOL shall be defined as any constructed pool, permanent or portable, which is intended for non-commercial use as a swimming pool by the owner family (ies) and its (their) guests, and which is over twenty-four inches (24") in depth and (a) has a surface area exceeding 250 square feet, or (b) a volume over 3,250 gallons.

A PUBLIC POOL shall be defined as any pool, other than a residential pool, which is intended to be used collectively by numbers of persons for swimming or bathing and is operated by any person be he owner, lessee, operator, licensee, or concessionaire, regardless of whether a fee is charged for such use. So that we may refer within the standard to various types of public pools they are listed in the following categories:

Type "A"	Any municipal, community, public school, athletic club or swimming club pool or pool for other similar usage and type.
Type "B"	Country club and institutional pools, such as for Girl Scouts, Boy Scouts, YMCA, YWCA, Campfire Girls, boys' camps, girls' camps, and for other similar type usage.
Type "C"	Pools for hotels, apartments and motels of more than 100 units.
Type "D"	Pools for motels and apartments, multiple housing units, and hotels of less than 100 units, not open to the general public.
Type "E"	Treatment pools, therapeutic pools and special pools for water therapy.

NATIONAL SWIMMING POOL INSTITUTE

MINIMUM STANDARDS FOR
PUBLIC POOLS

DESIGN AND STABILITY

1.1   Plans and specifications with supporting data, prepared by a
        registered architect or a professional engineer shall be
        submitted to, and approval obtained from, state or other
        local regulatory agency of the appropriate political
        subdivision, prior to construction.

1.2   Every public swimming pool shall have a minimum depth of water
        in the shallow end of the main swimming area of 3 ft., and a
        maximum depth of 5 ft. Exceptions may be made for Type E
        pools, or for pools designed for special use such as
        instruction, etc., or in a recessed area of the main
        swimming pool, outside of a competitive swimming course,
        where the pool is of an irregular shape.

1.3   A means of hydrostatic relief or means for positive and
        continuous drainage from under the pool floor or around the
        pool walls shall be provided for pools of rigid construction.

1.4   A public wading pool shall normally be a small pool for
        non-swimming children only, used for wading, and shall be a
        maximum depth at the deepest point not greater than 24".
        Where located adjacent to a swimming pool, consideration
        shall be given to minimizing the inadvertent entrance of
        a wader into the pool area.

1.5   A life line shall be provided two feet toward the shallow
        portion from the break in grade between the shallow and deep
        portions of the public swimming pool, with its position marked
        with colored floats at not greater than 5 ft. spacing. A life
        line shall be securely fastened in wall anchors of corrosion-
        resistant material and of the type which will be recessed or
        have no projection which will constitute a hazard.

1.6   Size of the pools shall be based upon the anticipated bather
        loads as follows: one person per 15 sq. ft. where water is
        less than 5 ft. in depth and one person per 20 sq. ft. of
        water over 5 ft. in depth, with the exclusion of
        300 sq. ft. for each diving board.

1.7   There shall not be any protrusions, extensions, means of
        entanglement or other obstructions which can cause the
        submerged entrapment of the bather.

MATERIALS AND FINISH

2.1   Swimming pools and all appurtenances thereto shall be
        constructed of materials which are non-toxic to man,
        impervious and enduring, which can withstand the design
        stresses, which will provide a watertight structure
        with a smooth and easily cleaned surface without cracks
        or joints, excluding structural joints, or to which a
        smooth, easily cleaned surface finish is applied or attached.

SLOPE OF SHALLOW AREA

3.1   The shallow portion of the pool shall be defined as the portion
        between the shallow end and either the 5' depth point or the
        break in grade, whichever is less. The slope of the floor in
        the shallow portion shall be uniform and shall not be greater
   than 1 ft. of slope in 10 ft.

VERTICAL WALL DEPTH

4.1   Walls in the deep portion of a pool shall be vertical for a
        minimum depth of 3'0". Vertical is interpreted to permit
        slopes not greater than one foot horizontally for each
        five feet of height of sidewall (11 from vertical).

4.2   Walls in the shallow portion of the pool shall be vertical for
        a minimum of 2'6", from which point a radius cove or vertical
        section may be used to join the wall section to the floor,
        with the minimum total shallow end depth being 3'0" in the
        swimming areas. More shallow depths may be used in the non-
        swimming areas except that in no case shall wall slopes exceed
        11 from vertical or floor slopes exceed 1 ft. of slope in
        10 ft. as outlined in 3.1.

DIVING AREA

5.1   The area of a public swimming pool where diving is permitted
        shall be, in the case of a rectangular pool, at the deep end,
        or may be in a recessed area forming one of the legs of a T,
        L or Z shaped pool, divorced from the main swimming area by
        a life line, or in Type A pools preferably a wholly
        separate pool structure. Exceptions to this may be made in
        special-purpose type pools intended for training and
        instructions.

5.2   Pools of the types wherein diving is permitted shall have
        adequate area and depth of water for safe diving and the
        minimum depth and area characteristics for this area shall
        be as indicated in the accompanying chart.

5.3   There shall be no obstruction extending from the wall or the
        floor into the clear area of the diving portion of the pool.
        There shall be a completely unobstructed clear distance of 16
        ft. above the diving board measured from the center of the
        front end of the board, and this area shall extend at least
        eight feet (8 ft.) behind, eight feet (8 ft.) to each side and
        sixteen feet (16 ft.) ahead of the measuring point.

MINIMUM STANDARDS for PUBLIC SWIMMING POOLS
DIVING AREA- SCHEDULE of DEPTHS and THEIR LOCATIONS
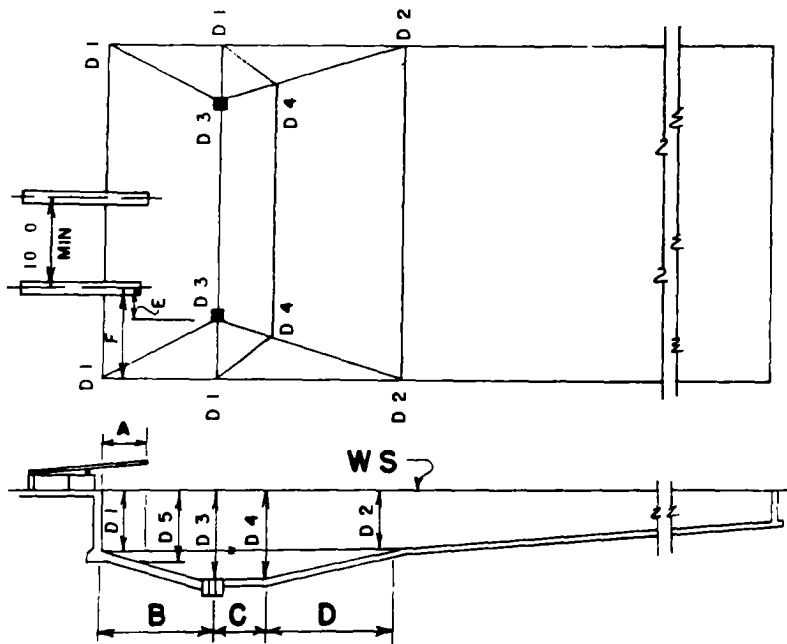
D-I Shall be at End Wall of Diving Area or Not More Than 12" From This Wall

STANDS & BOARDS		DEPTH MIN - MAX					LENGTH of SECTION					
		D 1	D 2	D 3	D 4	D-5	A	B	C	D	E	F
3 METER BOARD	MIN	5 0	4 6	11 0	9 9	8 6	5 0	6 0	9 0	20 0	1 0	12 0
	MAX		5 6				6' 0	10 0"				
1 METER BOARD	MIN	5 0	4 6	9 0"	8 3	7 6	5 0	6 0	9 0"	15 0	1 0	10 0
	MAX		5 6				6-0"	10 0"				
DECK LEVEL BRD	MIN	5 0"	4 6	8 0	7 6		2 6"	6 0"	6-0"	12 0"	1 0	10-0
	MAX		5 6"				4' 0"	10' 0"				
NO BOARD	MIN	NO DIVING				"B & "C May Vary to Attain Total 15 0 MIN						
	MAX					"B & "C May Vary to Attain Total 12 0 MIN						

MINIMUM STANDARDS for PUBLIC SWIMMING POOLS DIVING AREA-SCHEDULE

DIMENSIONS FOR DIVING FACILITIES
FINA International Amateur Swimming and Diving Federation

LONGITUDINAL	DIAGRAMMATIC	CROSS SECTION
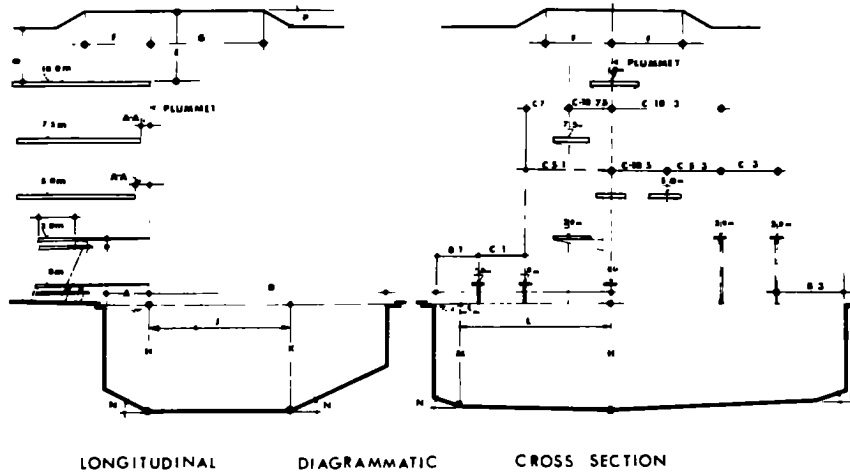
FINA INTERNATIONAL AMATEUR SWIMMING AND DIVING FEDERATION DIMENSIONS FOR DIVING FACILITIES		1 meter Springboard	3 meter Springboard	1 m platform	3 m platform	5 meter Platform	7.5 meter Platform	10 meter Platform
A	FROM PLUMMET S CL TO POOL WALL	A 1 5	A 3 5	4	4	A 5 4	A 7 5	A 10 5
AA	BACK TO PLATFORM DIRECTLY BELOW	-	-	-	-	AA 5/1 2 6	AA 7.5 2 6 AA	AA 10.5 2 6
B	FROM PLUMMET TO POOL WALL AT 5 DK	B 1 8	B 3 12	7 6	9 6	B 5 14	B 7 15	B 10 17
C	FROM PLUMMET TO ADJACENT PLUMMET	C 1 6	C 3 6	C 3-1 6		C 5 3 7	C 5 1 7 C 7.5 1 7 C 10 7	C 10.5 9 C 10 3 9
D	FROM PLUMMET TO POOL WALL AHEAD	D 1 29	D 3 34	26	31	D 5 34	D 7 36	D 10 45
E	PLUMMET FROM BOARD TO CEILING OVERHEAD	-	E 1 16	-	E 3 16	16	16	E 5 16 E 7.5 16	E 10 11
F	CLEAR OVERHEAD BEHIND AND EACH SIDE PLUMMET	F 1 8	16	F 3 8	F 3 16	9	9	F 5 9 10	F 7.5 9 F 10 9	F 10 -
G	CLEAR OVERHEAD AHEAD OF PLUMMET	G 1 16	16	G 3 16	G 3 16	16	16	G 5 16	G 7.5 16	G 10 20
H	DEPTH OF WATER AT PLUMMET	-	H 1 11	-	H 3 12	11	11	H 5 12	H 7.5 13 6	H 10 15
J-K	DISTANCE DEPTH OF WATER AHEAD OF PLUMMET	J 1 20	K 1 10 9	J 3 20	K 3 11-9	10/10.6	10/10 9	20	K 5 11 9	J 7.5 26	K 7.5 13	J 10 40	K 10 14
L-M	DISTANCE AND DEPTH OF WATER EACH SIDE OF PLUMMET	L 1 8	M 1 18 9	L 3 10 6	M 3 11 9	7/10 9	9/10 9	L 5 14	M 5 11-9	L 7.5 15	M 7.5 13	L 10 17	M 10 14
N/P	MAXIMUM ANGLE OF SLOPE TO REDUCE DIMENSION BEYOND FULL REQUIREMENTS	POOL BOTTOM CEILING HEIGHT	30 Deg. (App. maxly 1 foot in 2 horizontal) 30 Deg.						

DIMENSIONS FOR DIVING FACILITIES

5.4   Public pools with diving facilities in excess of 3 meters in
        height or pools designed for high platform diving shall comply
        with national and international required dimensions for such
        facilities (See FINA dimensions).

LADDERS AND STAIRS

6.1   Stairs, ladders or recessed steps shall be provided at the
        shallow portion of the swimming pool if the vertical distance
        from the bottom of the pool to the deck or walk is over two
        feet. Stairs, ladders or recessed steps shall be provided at
        the deep portion of the swimming pool except in Type E.
        If the pool is over 30 feet wide, such steps or ladders shall
        be installed on each side. There shall be a clearance of not
        more than six inches nor less than three inches between any
        ladder and the pool wall.

6.2   Stairs, ladders and recessed steps should be so located so as
        not to interfere with racing lanes.

6.3   In a Type E pool, ledges, steps and seats may be provided and
        in other type pools these units may be provided in a
        segregated section such as an alcove or wing of the pool.

DECKS AND WALKWAYS

7.1   Walks shall be continuous around the pool with a minimum width
        (as listed below) of unobstructed clear distance including a
        curb at the pool edge, if such a curb is used.

            A - 8 ft.   C - 4 ft.   E - no minimum
            B - 4 ft.   D - 4 ft.

7.2   A minimum of a 2 ft. walk width shall be provided on the sides
        and rear of any piece of diving equipment.

7.3   All walks, decks and terraces shall be uniformly sloped to
        drains or points at which the water will have a free
        unobstructed flow to points of collection at all times.

7.4   The finish texture of walks must be non-slip and such that
        there will be no discomfort to bare feet.

7.5   Hose bibbs of not less than 3/4" should be provided around the
        perimeter of the deck area at intervals such that all parts of
        the swimming pool deck area may be reached with a 75 ft. hose.

DEPTH MARKINGS AND LINES

8.1   Depth of water shall be plainly marked at or above the water
        surface on the vertical pool wall or on the edge of the deck or
        walk next to the pool, at maximum and minimum points and at the
        points of break between the deep and shallow portions and at
        intermediate increments of depth, spaced at not more than 25
        ft. intervals.

8.2   Depth markings shall be in numerals of 4" minimum height and
        of a color contrasting with background. Markings shall be on
        both sides and ends of the pool.

LIGHTING AND WIRING

9.1   Where underwater lighting is used, not less than 0.5 watts
        shall be employed per square foot of pool area. Where
        competitive swimming is contemplated underwater lights should
        not be placed in the end walls of the pool.

9.2   Where underwater lighting is used, and night swimming is
        permitted, area lighting shall be provided for the deck areas
        and directed toward the deck areas and away from the pool
        surface insofar as practical in a total capacity of not less
        than 0.6 watts per square feet of deck area. Where
        underwater lighting is not employed and night swimming is
        permitted, area and pool lighting combined shall be provided
        in an amount of not less than 2 watts per square foot of
        pool and deck area.

9.3   All wiring in connection with requirements for a swimming pool
        for lighting or power shall conform with Article No. 680 of the
        National Electric Code of the National Fire Protection
        Association.

WATER SUPPLY

10.1   The water supply serving the pool shall meet the requirements
        of the health department for potable water except that the
        health officer may approve the use of water from natural
        sources, including saline water.

10.2   All portions of the potable water supply system serving the
        swimming pool and auxiliary facilities shall be protected
        against backflow.

10.3   Potable water introduced into the swimming pool, either
        directly or to the recirculation system, shall be supplied
        through an air gap (American Standards Association A40.4-1942)
        or other approved means.

INLETS AND OUTLETS

11.1   Pool inlets and outlets shall be provided and arranged to
        produce a uniform circulation of water and the maintenance
        of uniform chlorine or equivalent disinfectant residual
        throughout the pool; provisions shall be made to adjust
        the flow through all inlets.

11.2   The number of inlet(s) shall be based on either one inlet per
        600 sq. ft. of pool area or one inlet per 15,000 gallons of
        pool capacity, whichever is greater.

11.3   When the outlets for pool pump suction are installed in the
        pool floor near one end, the spacing shall not be greater than
        20 ft. on centers and an outlet shall be provided not more
        than 15 ft. from each side wall. At least one outlet shall
        be provided at the lowest point of the floor to completely
        drain the entire floor area. The floor outlet shall not
        permit a flow of water greater than 2 ft. per second through
        the grating and slotted openings in the grate shall not be
        over 1/2" wide.

11.4   Where one outlet is used it shall be of the anti-vortex type
        or otherwise sized to preclude being blocked by a bather.

11.5   Where outlet fittings consist of parallel plates, of
        anti-vortex type where the water enters the fittings from the
        sides, rather than through a grating facing upward, entrance
        velocities may be increased to 6 ft. per second.

RECIRCULATION AND FILTRATION

12.1   All public swimming pools shall have recirculation and
        filtration equipment in accordance with criteria in these
        standards.

12.2   This equipment shall be of adequate size to turnover the
        entire pool water capacity at least three (3) times every
        twenty-four (24) hours.

12.3   A wading pool shall have equipment of adequate size to turnover
        the pool water capacity at least six (6) times every
        twenty-four (24) hours.

12.4   All equipment shall be designed and fabricated to drain
        completely, together with exposed face piping, by removal
        of drain plugs and manipulating winter drain valves or other
        methods.

12.5   Pool piping shall be sized to permit the rated flows for
        filtering and cleaning without exceeding the maximum head at
        which the pump will provide such flows.

12.5.1   The water velocity in the pool piping shall not exceed ten
         (10) feet a second for discharge piping, except for copper
         pape where the velocity shall not exceed six (6) feet a second
         discharge. Suction velocity for piping shall not exceed six
         (6) feet a second for both. Where velocities exceed these
         rates summary calculations should be provided to show that
         rated flows are possible with the pump and piping provided.

12.5.2   The recirculating piping and fittings shall be of non-toxic
         material resistant to corrosion, and able to withstand
         operating pressures.

12.5.3   All piping around the pool shall be sloped for adequate
         drainage and supported at sufficiently close intervals so that
         sagging between supports will not trap water. Provisions
         shall be made for expansion and contraction of pipes by means
         of swing joints or other means, as required.

12.6   At all pressure filter plants where the circulating pump is
         used for vacuum cleaning or draining the pool, a suitable
         strainer or screen shall be provided before the pump to
         remove solids, debris, hair, lint, etc. Where a
         wet well is provided the strainer shall consist of a
         removable screen; all water entering the pump shall pass
         through the screen.

12.7   An overflow collection system, automatic surface skimmers or
         other satisfactory overflow surface cleaner shall be installed
         around all public swimming pools.

12.7.1   The term "overflow systems" as herein used is a replacement for
         the traditional term "gutter." This encompasses rim type
         overflows, surface skimmers and collection systems of various
         design and manufacture.

12.7.2   The overflow system shall be designed and constructed so that
         the level of the pool is maintained at the operating level of
         the rim or weir device at all times.

12.7.3   Rim type overflow systems shall extend around a minimum of 50%
         of the perimeter of the pool. Recirculating type rim overflow
         systems shall be capable of continuously removing 50% or more of
         the recirculated water through the filter system. All fixed rim
         overflow systems shall be connected to the recirculation system
         with a surge capacity of not less than one-half gallon for each
         square foot of pool surface area.

12.7.4   In swimming pools subject to heavy bathing loads, the surge
         capacity shall be increased to not less than one gallon for each
         square foot of surface area.

12.7.5   The overflow system, in combination with the upper rim of the
         pool, shall constitute a handhold subject to accepted standards.

12.7.6   Nothing in this section shall preclude the use of roll out or
         deck level type swimming pools, but in the case of competitive
         pools, the ends of the pool must provide a visual barrier that
         can be seen by swimmers. Also, in the case of competitive
         pools, the system design shall provide and aid in creating a
         smooth water surface to enhance the performance of the swimmer.

12.7.7   Permanently installed skimmers shall comply in all respects with
         the Joint National Swimming Pool Institute-National Sanitation
         Foundation "Standard Relating to Recessed Automatic Surface
         Skimmers for Swimming Pools" and shall bear the seal of an
         approved testing laboratory. Surface skimmers of approved type
         may be used on public swimming pools of all types.

12.7.8   One skimming device shall be provided for each 500 sq. ft. or
         fraction thereof, of the pool surface area.

12.8   Every public swimming pool shall be provided with a rate of flow
         indicator.

12.9   Pump and motor shall be provided for recirculation of the pool
         waters. Pumps of 3 hp. or smaller shall comply in all respects
         with the Joint National Swimming Pool Institute-National
         Sanitation Foundation "Standard Relating to Centrifugal Pumps
         for Swimming Pools" and shall bear the seal of an approved
         testing laboratory. Performance of all pumps shall meet the
         conditions of quantity required for filtering and cleaning the
         filters with the total dynamic head developed by the complete
         system.

12.9.1   The pump performance curve for the unit to be installed shall be
         provided and submitted to proper authorities for review and
         approval.

12.9.2   On Type A pools the pump suction header shall be provided with
         a gauge(s) which indicate both pressure and vacuum; it shall be
         installed as close to the pump inlet as possible.

12.10   Complete instructions, in duplicate, shall be furnished by the
         builder, with such drawings, tagging all drains and valves,
         etc., as necessary, to clearly define the required procedures.

FILTERS

13.1   All diatomite and sand filters, whether of the vacuum or
        pressure type, shall comply in all respects with the
        appropriate Joint National Swimming Pool Institute-National
        Sanitation Foundation Standards covering such filters and
        shall bear the seal of an approved testing laboratory.

DISINFECTANT AND CHEMICAL FEEDERS

14.1   A means of disinfecting the pool water shall be employed
        which provides a disinfecting residual in the pool water.
        Chlorine or chlorine compounds are most frequently used
        for this purpose but other elements in the halogen
        group, bromine or iodine, shall be acceptable.

14.2   Adequate and appropriate feeding and regulating equipment for
        introducing a disinfectant into the recirculating system shall
        be provided. Equipment for supplying chlorine or compounds
        of other approved disinfecting agents shall be of sufficient
        capacity to maintain a residual in the pool at all times
        equivalent to .6 to 1.0 ppm of free available chlorine.

14.3   Feeding equipment shall be of enduring type which will
        permanently and precisely feed the required amounts of the
        disinfecting agent to maintain a consistent residual in the
        pool water, and the disinfecting material used shall be
        subject to a testing procedure of a simple type which will
        permit a ready means of field determination of the residual.

14.4   In cases where elemental chlorine is supplied, a water operated
        gas chlorinator will be used which controls and regulates the
        flow of the gas. This unit will provide an automatic shut off
        of gas when water pressure fails and will vent leakage to
        outside atmosphere.

14.5   (a) Hypochlorinators or other adjustable output rate chemical
             feeding equipment shall conform to the Joint National
             Swimming Pool Institute-National Sanitation Foundation
             Standard Relating to Adjustable Output Rate Chemical
             Feeding Equipment for Swimming Pools and shall bear the
             seal of an approved testing laboratory.

        (b) Capacities should be adequate to conform to the
             requirements of 14.2.

(c) No cross-connection with domestic water supply shall
be permitted.

(d) Hypochlorinator shall include some positive feature to
prevent siphoning when installed above the pool.

14.6 Where gaseous chlorine equipment is provided below grade in a
filter room or in any part of a building which provides
housing: (a) The mechanical proportioning device and
cylinders of chlorine shall be housed in a reasonably
gas-tight corrosion-resistant and mechanically vented
enclosure, (b) Air tight ducts from the bottom of the
enclosure to atmosphere in an unrestricted
area and a motor driven exhaust fan capable of producing
at least one air change per minute shall be provided,
(c) Automatic louvers of good design near the top of the
enclosure for admitting fresh air are required, (d) Elec-
trical switches for the control of artificial lighting and
ventilation shall be on the outside of the enclosure adjacent
to the door, (e) The floor area of the enclosure shall be of
adequate size to house the chlorinator, (f) Gas mask
approved by the Bureau of Mines for protection against
chlorine gas shall be provided, mounted outside the chlorine
compartment, and (g) It is highly recommended that a Chlorine
Institute approved safety kit be stored outside
or be near the room where chlorine cylinders are stored and
used.

WASTE WATER DISPOSAL

15.1 Overflow water should return to the filter system or may be
discharged to a waste system approved by the local authorities.
Where overflow gutter water discharges into a sanitary sewer,
a suitable air gap of not less than 1" shall be provided which
accomplishes a gravity drop into the sewer without direct
mechanical connection.

15.2 In lieu of the air gap, as described above, and where this
cannot be practicably provided, a relief manhole may be
constructed in the gutter main waste line with a grated cover,
the clear area of which shall be twice the area of the main
waste piping, and this shall be established at a level such
that the waste flow in the line will raise in the manhole and
overflow at the surface of the ground not less than 2 ft.
below the level of the overflow gutter lip.

15.3 The disposition of sanitary sewage from the bathhouse shall
be into a sanitary sewer, a septic tank or other waste line
which meets with the approval of local health authorities.

15.4 Backwash water may be discharged into a sanitary sewer through
an approved air gap or to an approved subsurface disposal
system or by other means approved by local authorities.

BATHHOUSES

16.1   Adequate dressing and sanitary plumbing facilities shall be
        provided for every public swimming pool. An exception to this
        may be made in Types B, C, D, and E pools where available
        facilities are provided in connection with the general
        development for other purposes, etc., of adequate
        capacity and number, in close proximity to the pool.

16.2   Every bathhouse shall be provided with separate facilities for
        each sex with no inter-connection between the facilities for
        male and female. The rooms shall be well-lighted, drained,
        ventilated and of good construction, with impervious materials
        employed in general, finished in light colors and so
        developed and planned that good sanitation can be maintained
        throughout the building at all times.

16.3   All partitions between portions of the dressing room areas,
        screen partitions, shower, toilet and dressing room booths
        shall be of durable material not subject to damage by water
        and shall be so designed that a water way is provided between
        the partitions and floor to permit thorough cleaning of the
        walls and floor areas with hoses and brooms.

16.4   Shower and dressing booths shall be provided in female
        dressing space and dressing booths shall be provided with
        curtains or other means of seclusion. This condition may be
        subject to variation for schools and other institutional
        use where a pool may be open only to one sex at a time.

16.5   The floors of the bathhouse shall be free of joints or openings
        and shall be continuous throughout the area with a very slight
        texture to minimize slipping but which shall be relatively
        smooth to ensure complete cleaning. Floor drains shall be
        provided to ensure positive drainage of all parts of
        the building with an adequate slope in the floor toward the
        drains.

16.6   An adequate number of 3/4" hose bibbs shall be provided for
        flushing down the dressing rooms and bathhouse interior.

16.7   Not less than one drinking fountain shall be provided
        available to bathers at the pool and in the bathhouse.

TOILETS AND SHOWERS

17.1   Minimum sanitary plumbing facilities shall be provided as
        follows. These minimum criteria for bathhouse plumbing
        facilities shall be based upon the anticipated maximum
        attendance in bathers. Facilities for either sex shall be
        based upon a ratio of 60% of the total number of bathers being
        male and 40% being female, excepting where pool is confined
        to use by one sex only, wherein 100% of plumbing facility
        requirements shall be provided for that sex.

17.2   One water closet combination, one lavatory and one urinal shall
        be presumed to be adequate for the first 100 male bathers.
        One additional water closet, lavatory and urinal shall be
        provided for each additional 200 male bathers or major fraction
        thereof.

17.3   Three shower heads shall be provided for the first 150 males
        and one shower head shall be provided for each additional 50
        male bathers. In type "D" pools one shower head would be
        adequate.

17.4   A minimum of two water closet combinations shall be provided
        in each bathhouse building for the first 100 females. One
        additional water closet combination and lavatory shall be
        provided for each additional 100 females or fraction thereof.
        In type "D" pools only one water closet combination is
        needed.

17.5   A minimum of two shower heads shall be provided, which shall
        be presumed to be adequate for the first 100 females and one
        shower shall be added for each 50 additional females. Type
        "D" needs only one shower head.

17.6   Tempered water only will be provided at all shower heads.
        Water heater and thermostatic mixing valve shall be
        inaccessible to bathers and will be capable of providing 2
        gpm of 90F. water to each shower head.

17.7   Soap dispensers for providing either liquid or powdered soap
        shall be provided at each lavatory and between each pair
        of shower heads and dispensers must be of all-metal or
        plastic type and no glass permitted in these units.

17.8   Mirrors shall be provided over each lavatory and toilet paper
        holders shall be provided at each water closet combination.

FOOD SERVICE

18.1   Where provision is made for serving food and/or beverages at
        the pool, no containers of glass shall be used. The area
        shall be so arranged and posted to prohibit the consumption
        of food and beverages on the pool walks as defined
        in 7.1.

SAFETY REQUIREMENTS

19.1   Each public swimming pool shall have at least one elevated
        lifeguard chair for 2,000 sq. ft. of pool surface or major
        fraction thereof. Where a pool is provided with more than
        one lifeguard chair and the pool width is 40 ft. or more,
        they shall be located on each side of the pool. In Type
        D" pools with area of 1,200 sq. ft. or less, and in all
        Type "E" pools, lifeguard chairs need not be provided.

19.2   One unit of lifesaving equipment shall consist of the
        following: A Coast Guard approved ring buoy with a minimum
        outside diameter of 20" (U.S.C.G. approval numbers 160.009 or
        160.050) to which shall be attached a length of 1/4" rope,
        not less than 1-1/2 times the maximum width of the pool; a life
        pole or shepherd's crook with minimum length handle of 12 ft.
        One unit shall be provided for each 2,000 sq. ft. of pool area
        or major fraction thereof.

19.3   Lifesaving equipment shall be mounted in conspicuous places,
        distributed around the pool edge, at lifeguard chairs, or
        elsewhere, ready of access, its function plainly marked.

19.4   Outdoor swimming pools shall be protected by a fence, wall,
        building, enclosure or solid wall of durable material of which
        the pool itself may be constructed or any combination thereof.
        Artificial barriers shall be constructed so as to afford no
        external handholds or footholds, of materials which are
        impenetrable by toddlers, at least 4 feet in height so that a
        toddler cannot grasp its top by jumping or reaching, and
        equipped with a self-closing and positive self-latching
        closure mechanism at a height above the reach of
        toddlers and provided with hardware for permanent locking.

19.5   Access to the pool by bathers shall be provided through the
        bathhouse or dressing room facilities if possible.

19.6   A telephone should be provided in the immediate deck area
        for possible emergency needs.

POOL MANAGERS

20.1   Individuals shall be qualified in pool and filter operation
        and sanitation as provided by the state health department or
        similar agency.

PERSONNEL

21.1   Each public swimming pool shall be under the supervision of a
        person qualified in the fields of life saving, first aid,
        filter operation and sanitation or under whose direct
        supervision are employed persons qualified in the
        above. Individuals shall be considered qualified in
        life saving and first aid if they hold the appropriate
        Red Cross certificate or equal.

21.2   In certain pools, particularly Type "D" and "E" - the owner
        may perform the functions noted above. In such cases,
        (and other exceptions may be noted) lifeguard protection
        cannot be provided at all times. At such times a warning
        sign shall be in plain view of all bathers indicating that
        lifeguard protection is not available.

<u>INSTRUCTIONS</u>

22.1   Upon the completion of any swimming pool, the manager and his
        operators shall be given complete written and oral instructions
        by the builder as well as operational guidance of the pool and
        all of the equipment and in the maintenance of the swimming
        pool water.

22.2   Pools with continuous overflow gutters, where surface
        skimmers are not employed, shall be operated in a manner
        so that the overflow gutter shall overflow freely and
        continuously, whether to waste or to the recirculation
        system, for a period of not less than one hour when the pool
        is closed for any daily operation and not less than one hour
        before the pool is opened for daily use by bathers. Also,
        the pool shall be filled to the elevation of the
        overflow gutter lip, making up the loss from displacement
        of bathers' bodies and splash-out, whenever the pool is
        closed to bathers for a period of one hour or more and when
        bathers are not in the pool, during daily operations.

APPENDIX B

THE CHEMISTRY OF THE pH FACTOR IN POOLS AND ITS
RELATION TO REACTIONS WITH NITROGENOUS SUBSTANCES

by

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Presented at NSPI Water Chemistry Seminar, January, 1964

When gaseous chlorine dissolves in water, it hydrolyzes rapidly
according to the equation

$$Cl(2) + H(2)O = H(+) + Cl(-) + HOCl$$
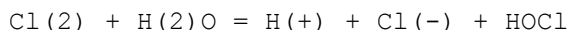
and the hydrolysis reaction goes substantially to completion at
concentrations of a hundred parts per million or less. At 18C (65 F)
the hydrolysis takes only a few tenths of a second; at 0C (32 F) a
few seconds is needed. A number of standard chemistry textbooks have
inaccurate statements about this process.
The hypochlorous acid (HOCl) tends to undergo a further reaction of
dissociation according to the equation

$$HOCl = H(+) + OCl(-)$$
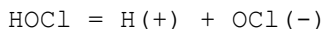
to produce hypochlorite ion and hydrogen ion. For most conditions of
use of chlorine and its compounds-that is, at concentrations of a
few parts per million or less in waters with reactions between pH 5
and 9-this reaction is incomplete so that both hypochlorous acid and
hypochlorite ion are present to some degree.
The extent of the reaction can be evaluated from the equation

$$K = H(+) (OCl(-)) / (HOCl)$$

in which K has a value about 2 x 10(-8) for 0C and about 3.2 x 10(-8)
for 25 when the concentrations of the substances are expressed in
molar terms. Rearrangement of this equation to the form

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$$\frac{(OCl(-))}{(HOCl)} = \frac{K}{(H(+))}$$

shows that the ratio of OCl(-) to HOCl will increase as (H(+)), the acid reaction, decreases. The logarithmic form

$$\log \frac{(OCl(-))}{(HOCl)} = pH - pK$$

shows the variation of this ratio with the pH of the water. pK, the negative logarithm of the ionization constant is almost exactly 7.5 at room temperature; at 0C it is 7.7.

When the pH value of the chlorinated water is 7.5, 50% of the dissolved chlorine will be present as HOCl and 50% will be present as OCl(-) ion. At greater pH values (more basic solutions) the concentration of OCl(-) will be greater than that of HOCl; at smaller pH values (more acid solutions) it will be less. The change is quite rapid, 90% is HOCl at pH 6.5, only 10% is HOCl at pH 8.5. Figure 1 shows the detailed variation of these relative concentrations with the pH of the solution.

Exactly the same considerations obtain when a hypochlorite is used instead of gaseous chlorine. If, for example, sodium hypochlorite (common bleach) is used, the initial dispersion in water is in accord with the equation

$$NaOCl \qquad Na(+) + OCl(-)$$

The hypochlorite ion then participates in exactly the same equilibrium reaction as before by combining with hydrogen ion.

$$OCl(-) + H(+) = HOCl$$
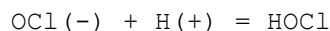
The only difference is that the use of hypochlorite tends to increase the pH of the water, whereas use of gaseous chlorine tends to decrease it. To the extent that the final pH differs because of the preliminary reactions the fractions of HOCl and OCl(-) will differ accordingly, but at a controlled pH even these will be the same.

Familiarity with these factors is essential to an understanding of the behavior of dilute chlorine solutions, for HOCl and OCl(-) have very different chemical and germicidal reactivities. The chemistry and the germicidal action of chlorinated water is dependent upon whether HOCl or OCl(-) is predominant, and hence upon the pH, which determines their ratio.

For example, a number of studies have shown that HOCl has, in general, about one hundred times the germicidal potency of OCl(-). As as a result, it takes about 10 times as much free aqueous chlorine to attain a given germicidal efficiency at pH 8.5, where only 10% HOCl is present as at pH 6.5, where 90% of the free chlorine is HOCl. Conversely, it is vital for interpretation of observed effects or for prediction of behavior under new conditions to have a knowledge of the chemical and germicidal properties of each of the active species, such as HOCl and OCl(-), that may be present in a chlorinated water. Apart from these species already considered major attention must be given to the compounds formed by the reactions of aqueous chlorine with nitrogenous substances.

In general, any compound containing a nitrogen atom with one or more attached hydrogen atoms will react with HOCl according to the schematic equation

$$N - H + HOCl \qquad N-Cl + H_2 O$$

The N-chloro compounds formed by this type of reaction show retention of the oxidizing capacity of the NOCl and thus tend to show the same analyses for available chlorine as pure aqueous chlorine solutions. However, in general the oxidizing power is less and the germicidal activity may be considerably less. The presence and form of such N-chloro compounds in a chlorinated water may, therefore, have a very pronounced effect on the chemical and germicidal characteristics. Formation of N-chloro compounds may be desirable in some circumstances because it can result in stabilization of residual chlorine, lessened chlorine demand with organic load and improved retention of germicidal action. In other circumstances formation of N-chloro compounds is undesirable because of impairment of germicidal action or production of noxious conditions. To understand and control these factors we need to know the rates of formation of these N-chloro compounds in dilute water solutions, their hydrolytic equilibria (which Dr. Robson will discuss) and their properties. Although the chemistry of their formation and behavior is often very complex, considerable progress is being made.

Of all the reactions of this type the ones with ammonia are probably the most universal and important. Since ammonia is present in almost all natural waters to some extent and since it may also enter pools from the skin or excretions of bathers, its reactions with aqueous chlorine will be of some concern for nearly all of water chlorination. Each of the hydrogens of the ammonia molecule, NH_3, may be replaced by

chlorine. The replacement reactions occur successively and in each
instance it is HOCl, specifically, that reacts. The successive
reactions are:

$$NH_3 + HOCl \quad NH_2Cl + H_2O$$
$$NH_2Cl + HOCl \quad NHCl_2 + H_2O$$
$$NHCl_2 + HOCl \quad NCl_3 + H_2O$$
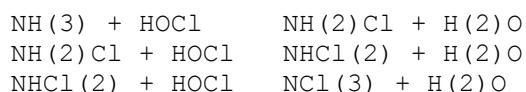
The extent of these reactions and the proportions of the three
products formed depend upon the pH, the temperature and the ratio of
aqueous chlorine to ammonia-nitrogen. Stoichiometrically it requires
5 parts of chlorine to each part of ammonia-nitrogen to form NH_2Cl
(chloramine, monochloramine or N-chloramide) completely, 10 parts of
chlorine to each of ammonia-nitrogen to form $NHCl_2$ (dichloramine;
dichloramide) and 15 parts of chlorine for each part of
ammonia-nitrogen to form NCl_3 (nitrogen trichloride, trichloramide).

However, because as soon as some of the first products are formed the
second and third reactions begin to compete with the first one for the
remaining free chlorine, the final products cannot be predicted fully
from these simple mass relationships.

The rate of the first reaction is very great in nearly waters, but is
strongly dependent on pH. Figure 2 presents some results obtained by
Dr. Weil and myself some years ago on the rate of this reaction. It
may be noted that the time for 90% completion of the reaction at a
1 ppm level of chlorine is only a small fraction of a minute at room
temperature between pH 7 and 9.5. The pH dependence of this reaction
is described accurately on the basis of the HOCl - OCl(-) equilibrium
and the NH_3 - $NH_4(+)$ equilibrium. Since most chlorination of
water takes place between pH 7 and 8.5 free chlorine is rapidly and
essentially completely removed when sufficient ammonia is present.
The second reaction, formation of $NHCl_2$ is faster than the first one
when the pH is less than 6, but becomes much slower at higher pH
values. This is shown in Figure 3 for a temperature of 25. Again
the pH dependence is predictable on the basis of the HOCl-OCl(-)
equilibrium; in this instance there is no second equilibrium process
to be concerned with for NH_2Cl is neither acid nor basic to any
significant extent.

In acid solutions less than pH 6 any NH_2Cl will compete effectively
as soon as it is formed with remaining NH_3 for whatever HOCl is still
present. So in these acid solutions one tends to get mixtures of
NH_2Cl and $NHCl_2$. In neutral or basic solutions the second
reaction is not able to compete so effectively with the first one
and so the portion of $NHCl_2$ drops off rapidly unless there is
an excess of chlorine greater than 5 parts of Cl_2 to 1 NH_3 - N.
The relative

amounts of NH(2)Cl and NHCl(2) formed as a function of pH with 5 parts of chlorine to 1 part of ammonia-nitrogen are shown in Figure 4. The rate of the third reaction, the formation of NCl(3), is not known quantitatively. This is unfortunate because of the importance of NCl(3) in chlorination of swimming pools. However, the instability of NHCl(2) has so far made impracticable the study of its further reaction with HOCl.

It is known quantitatively, of course, that formation of NCl(3) is favored by acid conditions and by large ratios of available chlorine to ammonia. One aspect of this is apparent. Formation of NCl(3) will occur only when NHCl(2) is present as a result of the preceeding reactions and so the slowness of formation of NHCl(2) in basic solutions tends to limit NCl(3) production. Figure 3 shows that at pH 8.5, for example, it may take as long as 300 minutes or 5 hours to form NHCl(2) at a concentration of 1-2 ppm. Another important factor is the instability of NHCl(2), the least stable of the chlorinated derivatives of ammonia. It is the decomposition of NHCl(2) that gives rise to the "breakpoint" phenomenon of water chlorination, in which ammonia-nitrogen is removed destructively and any residual chlorine exists as free HOCl or OCl(-). The rate of decomposition of NHCl(2) has been found to be dependent on pH and to increase with increasing pH particularly in basic solutions. Results of some measurements on this rate of decomposition are shown in Figure 5, together with a corresponding plot of the rate of formation of NHCl(2). Above a pH of 8.5 the rate of decomposition of NHCl(2) is greater than its rate of formation at the 2 ppm level. This means that there can be no build-up of NHCl(2) in these basic solutions and so formation of NCl(3) is further inhibited.

There is one complicating factor. It was observed in these studies that the decomposition of NCl(2) is much accelerated in the presence of an excess of HOCl, as indicated qualitatively by the dotted line in Figure 5. The main change introduced by this factor is to drop the crossover point for formation and decomposition about one pH unit. The prediction then is that at pH values greater than about 7.5 the rate of formation of NHCl(2) should control the rate of destruction of ammonia-nitrogen through the breakpoint reaction. Figure 6 shows the accord of this with experimental data. The points are measurements of the rate of loss of available chlorine by the "breakpoint" reaction. The line is the rate of formation of NHCl(2) computed from entirely different measurements. At pH 7.8 the points lie slightly below the line indicating that at this pH there may be some slight build-up of NHCl(2) and thus a possibility of NCl(3) formation, but at the higher pH values the agreement of the experimental rates with the prediction is remarkably good.

I should like to turn now to some considerations of another set of reactions-those between HOCl and sulfamate (the anion of sulfamic acid). Recent investigations on this system at Harvard-without particular reference to pool problems, I should say-have indicated nitrogenous materials. These studies have not yet been fully analyzed; so only some of the more dramatic results can be presented. We are again dealing with successive reactions

$$HOCl + NH_2SO_3(-)NHCLSO_3(-) + H_2O$$
$$HOCl + NHClSO_3(-)NCL_2SO_3(-) + H_2O$$
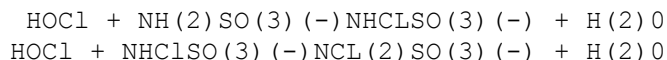
However, in the pH range of interest, near pH 7, the second of these reactions is 10 to 100 times as fast as the first one. This means that even with an excess of sulfamate present there is considerable tendency for the formation of dichlorsulfamate. The results in Figure 7 show this tendency for a pH of 8. One can observe from the ultra-violet spectra that even with a tenfold molar ratio of nitrogen to chlorine about 50% of the chlorine ends up in dichlorsulfamate. The tendency is even more pronounced at pH 7.

In Figure 8 the relative rate of the second reaction is compared with that of the first, computed from measurements like those of Figure 7, as shown as a function of pH. You will note the apparent maximum near pH 6.5. As yet no mechanism has been developed to account for this, so the lines, which are drawn to represent direct proportionality to pH and inverse proportionality to pH, must be regarded as tentative. As yet, because of the complications from the second reaction, there are no values for the absolute rate of the first reaction. It is, however, rather slow as compared with the reaction of HOCl with NH(3), so that free chlorine will persist for some time before its combination with sulfamate is complete.

The second noteworthy feature of the HOCl-sulfamate system is that dichlorsulfamate, in the presence of an excess of sulfamate, will slowly revert to monochlorsulfamate. This is shown in Figure 9. The spectra shows that even with quite high concentrations of chlorine and sulfamate the reversion according to the reaction.

$$NCl_2SO_3(-) + NH_2SO_3(-) \ 2NHClSO_3(-)$$
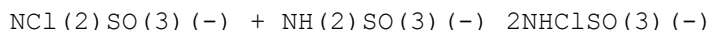
requires about 24 hours for completion at pH 7.8. Periods of a week or so might be expected at the concentrations used in pool treatment. In Figure 10 the variation of the rate of this reaction with pH is shown. A

rate of reversion directly proportional to pH is found, so that at pH 7 the reversion will take 5 to 10 times as long as at pH 7.8 and at pH 8.5 will proceed about 5 times as rapidly.

It is hoped that when this work is completed it will provide data so that the quantities of dichlorsulfamate and monochlorsulfamate can be evaluated for any conditions of operation and that this will enable other workers to evaluate more specifically the disinfecting activities of these compounds.

One other observation might be made. I understand that there is some disagreement about the sensitivity of chlorinated sulfamate to sunlight. Since the spectra shows that dichlorsulfamate absorbs light at 3000 A(o) - a wave length quite strong in sunlight - whereas monochlorsulfamate absorbs strongly only at a much shorter wave length, it is possible that dichlorsulfamate may be readily decomposed by sunlight and that monochlorsulfamate is not.
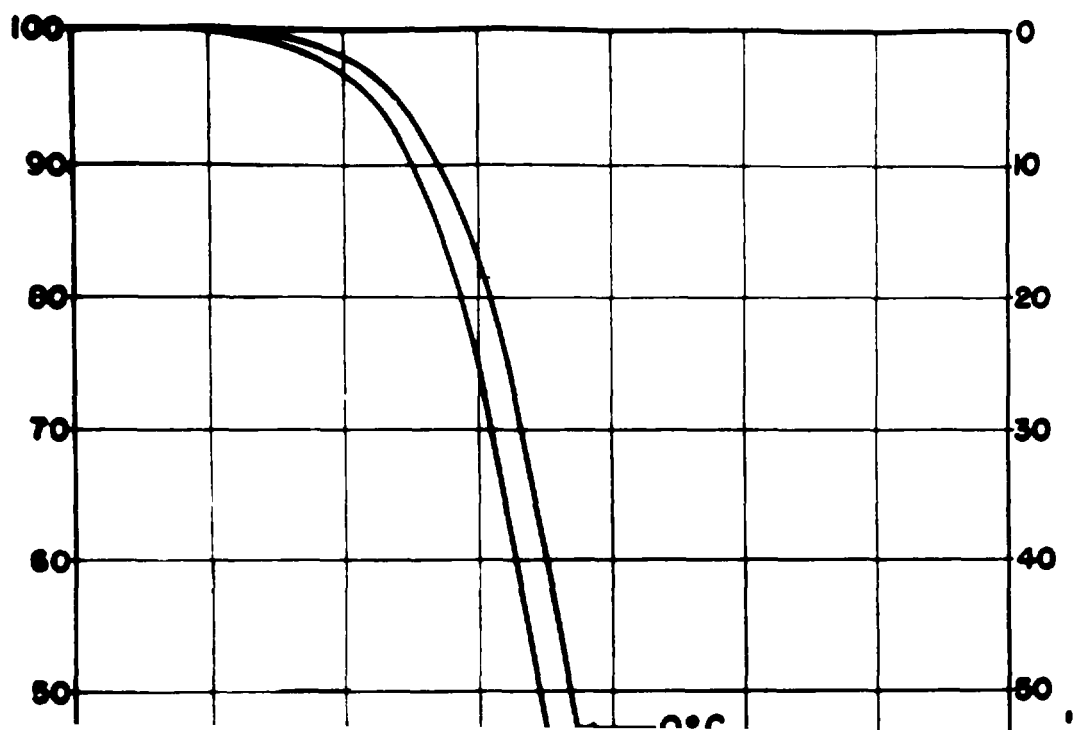
RELATIVE AMOUNTS OF HOCl AND OCl(-) PRESENT
AT VARIOUS pH VALUES
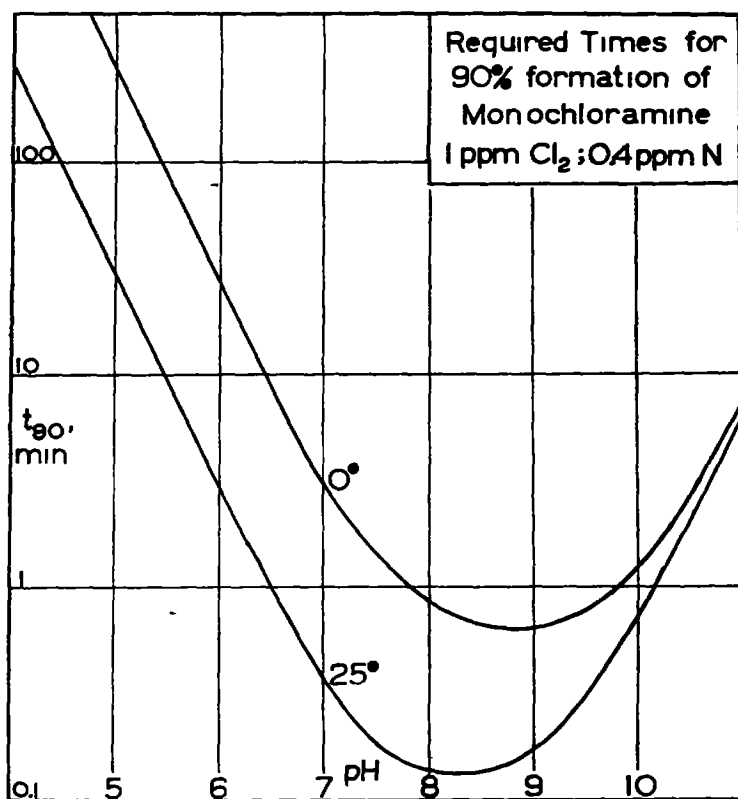
Figure 2
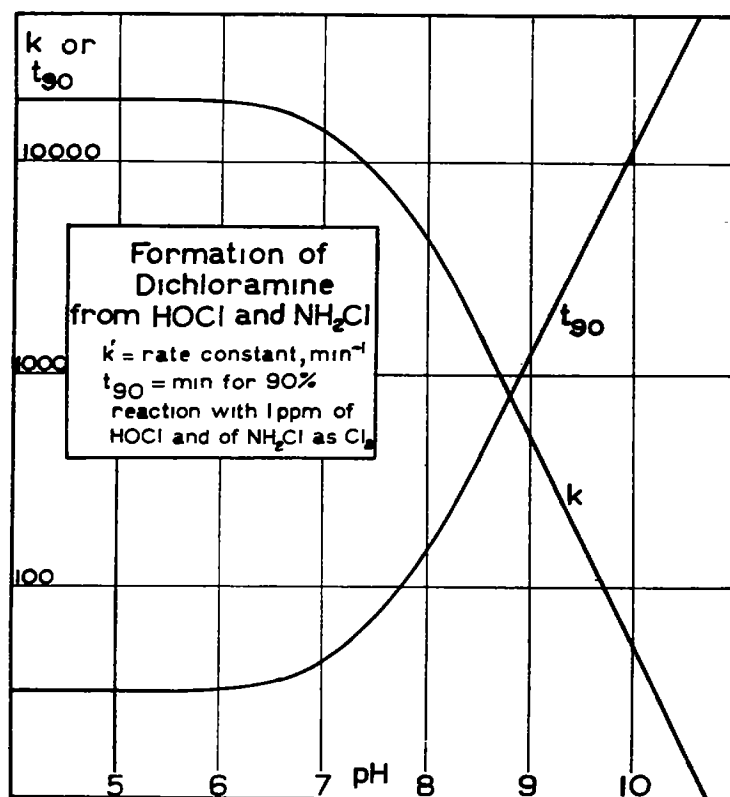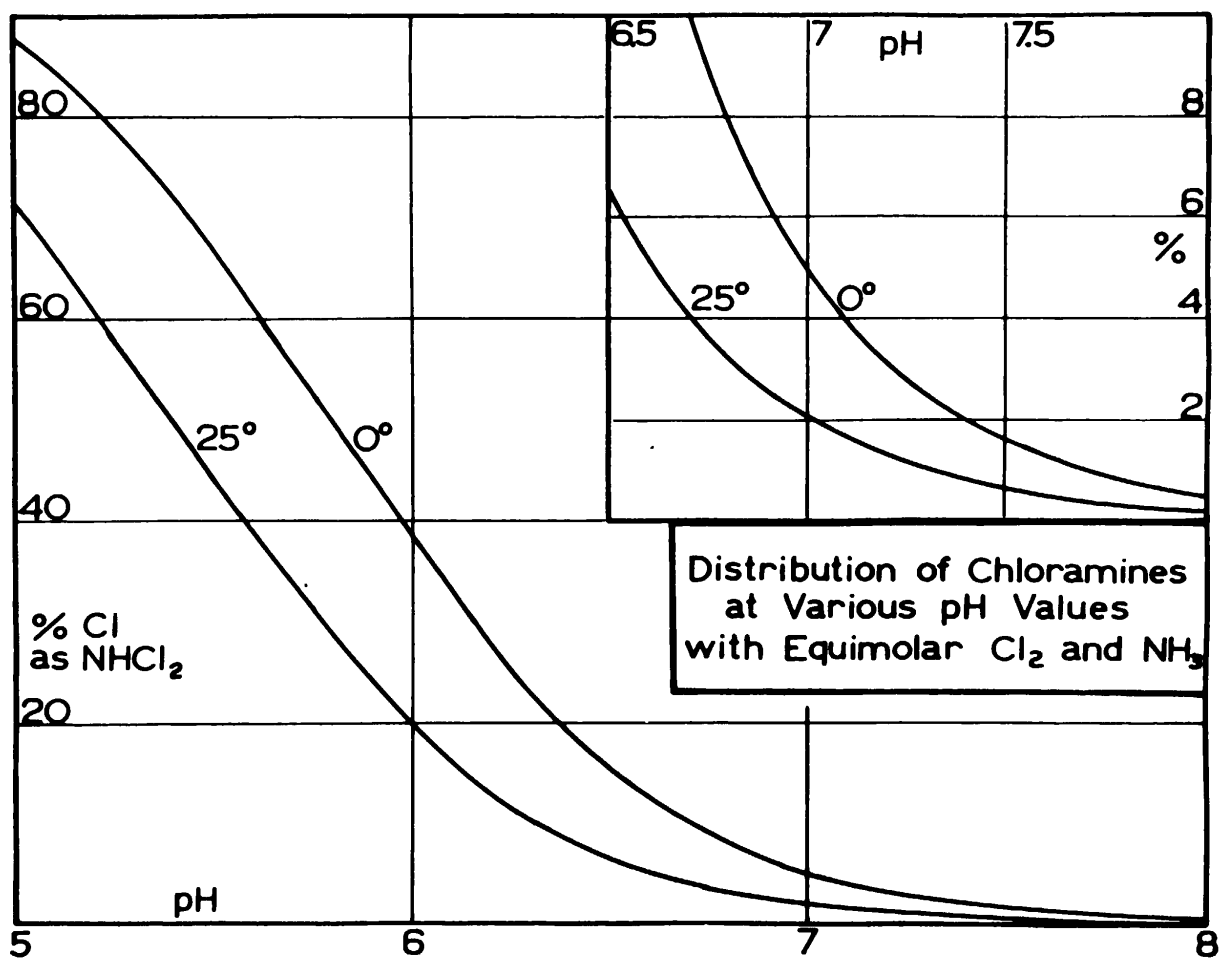
Required Times for 90% formation of Monochloramine

Figure 3

Formation of Dichloramine
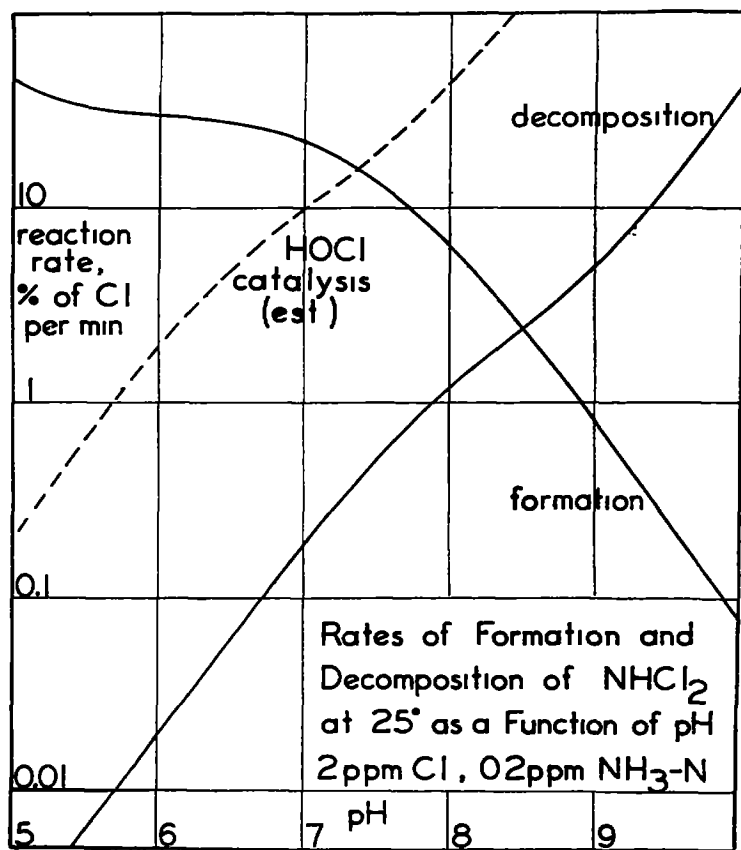
Distribution of Chloramines

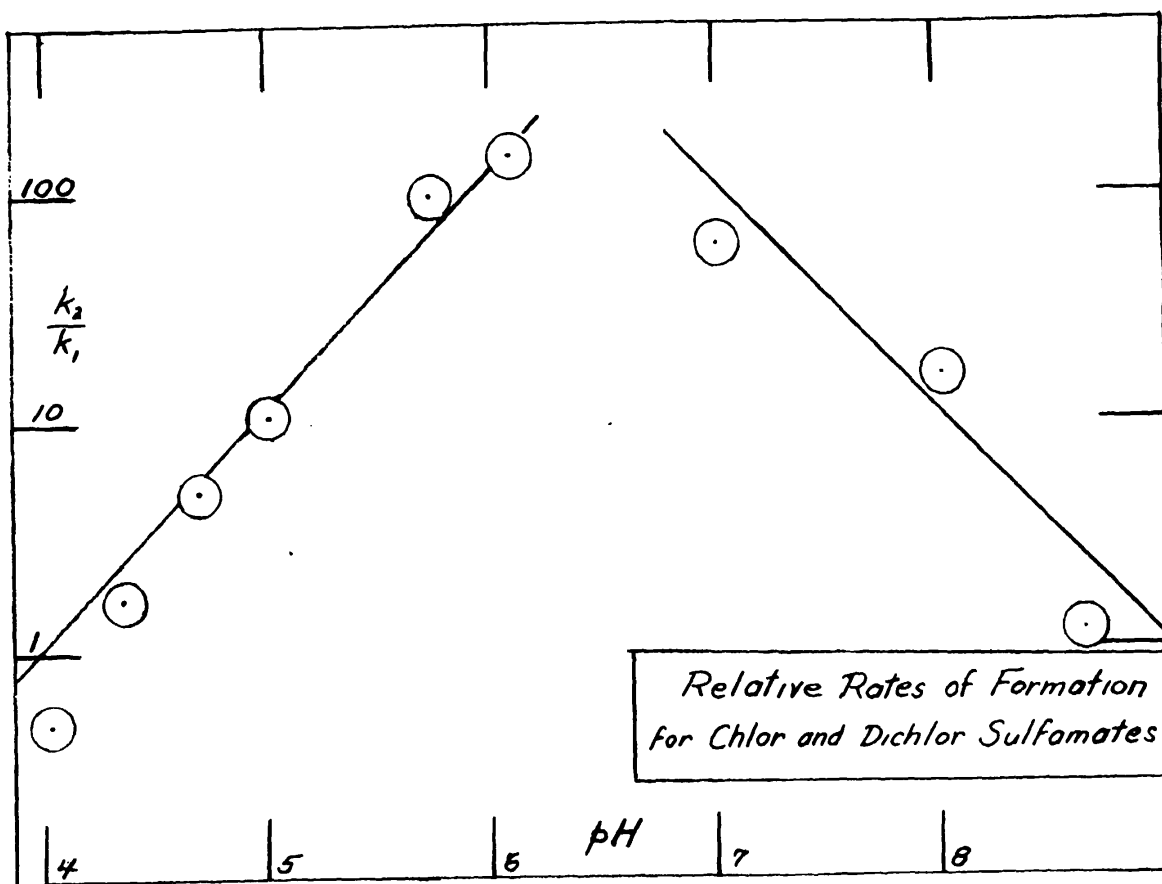**Figure 5**

Rates of Formation and Decomposition
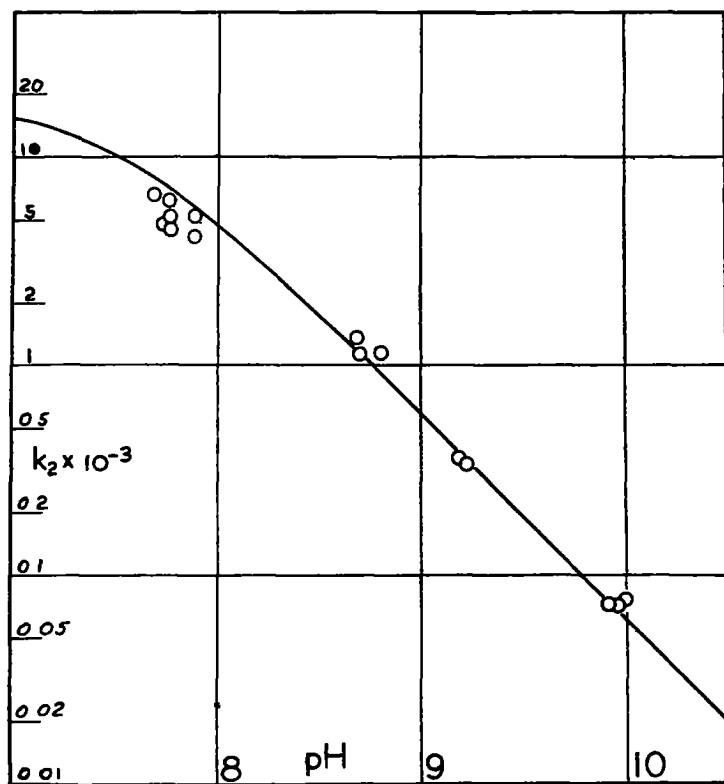
Figure 6

Figure 6

Chlorination of Sulfamate

pH·8; temp 25 C;
23 ppm Cl₂; 30 minutes

No.	ppm sulf.	N/Cl
1. pure dichlorsulfamate		
2.	31.0	1.0
3.	62.1	2.0
4.	155	5.0
5.	310	10.0
6. pure N·chlorsulfamate		

Absorbance, 10-cm cell

Wave length, mμ
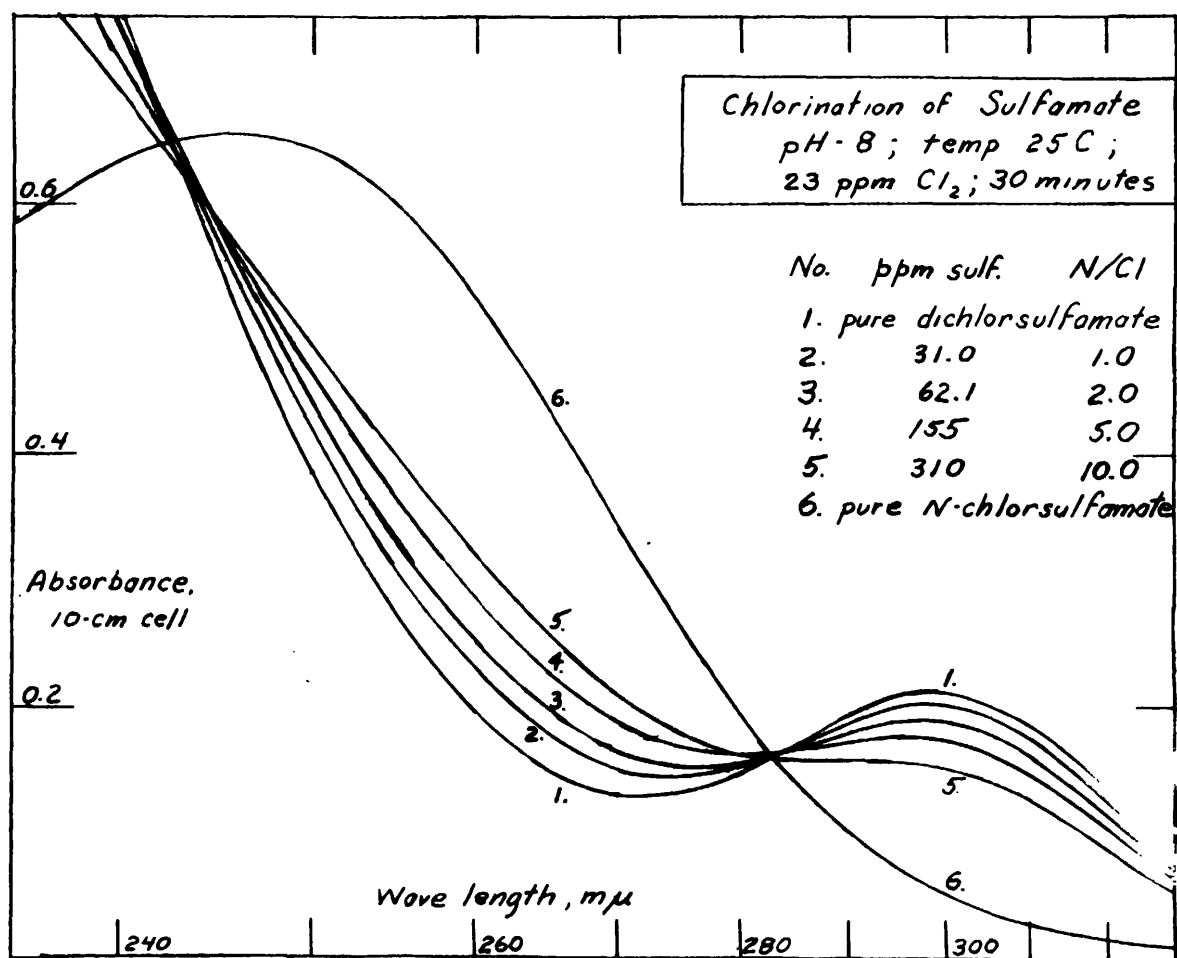
Chlorination of Sulfamate

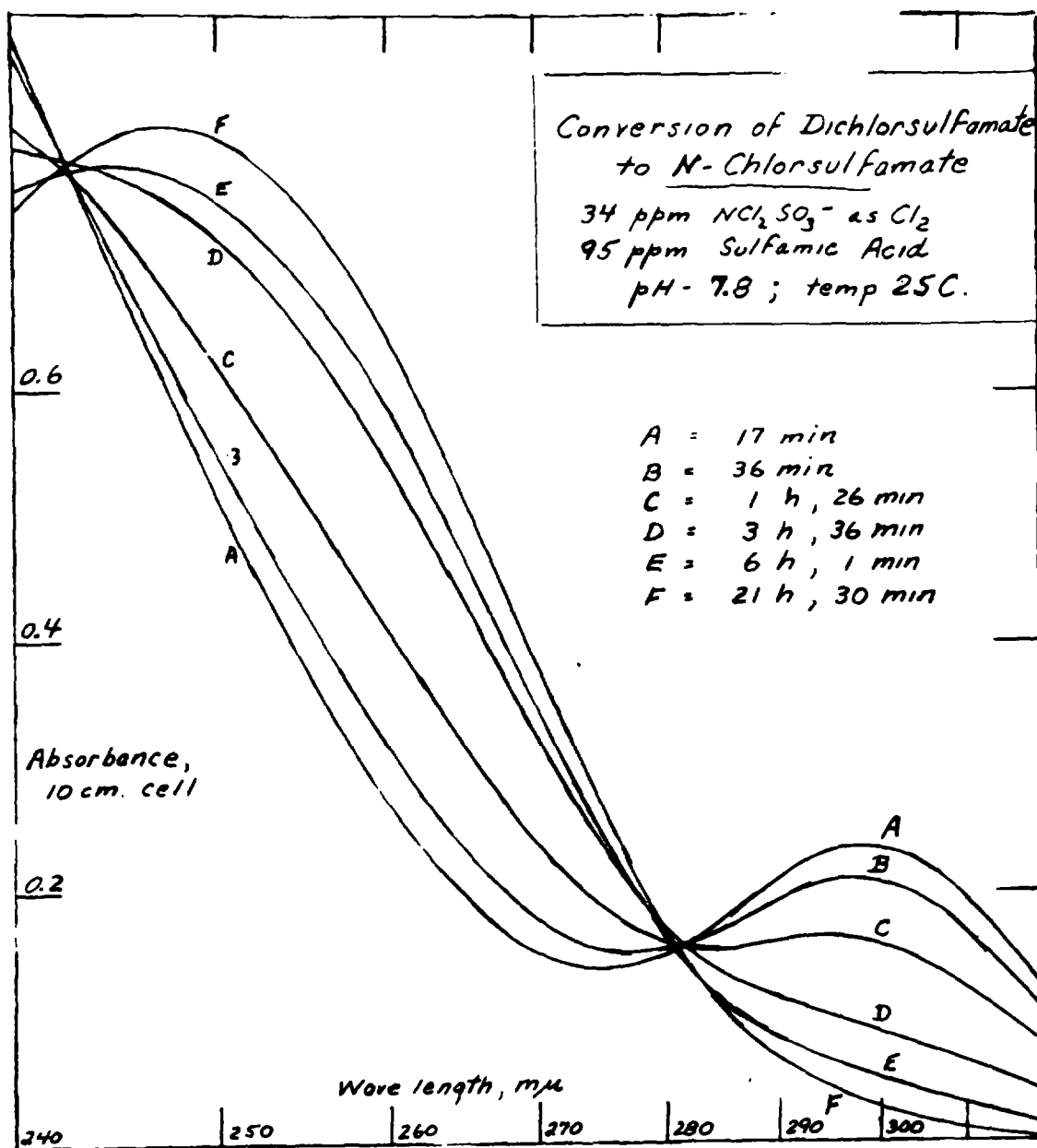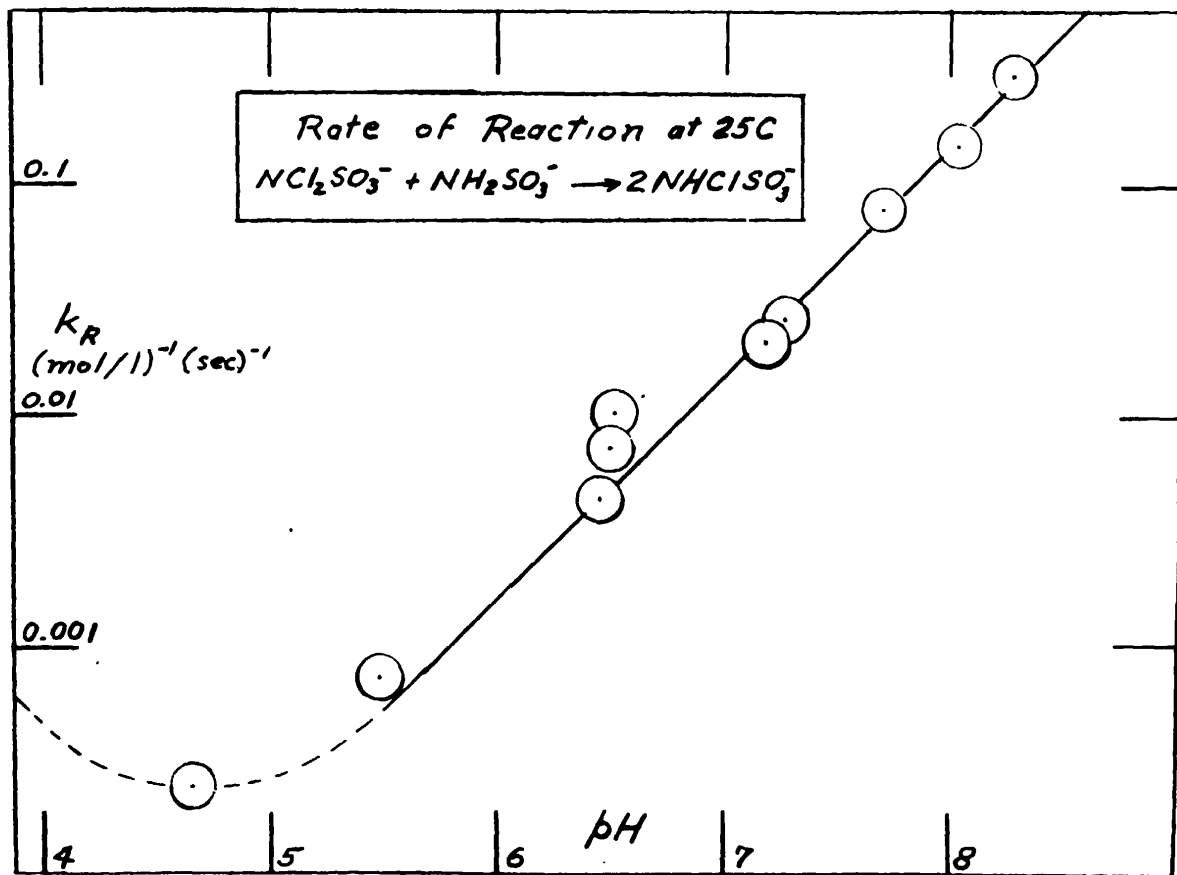Relative Rates of Formation for Chlor and Dichlor Sulfamates

Figure 9

Conversion of Dichlorsulfamate to N-Chlorsulfamate

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Rate of Reaction at 25C

BIBLIOGRAPHY and CREDITS

This manual is published by the National Swimming Pool Institute as one of its many services to the swimming pool industry and to the owners and operators of swimming pools.

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At the outset of study in preparation for this manual, a search was made for publications which deal specifically with swimming pool operation and related technology. Of those publications discovered, the following were found helpful in contributing information and perspective:

Swimming Pool Operation, State of Illinois Department of Health

Swimming Pool Operation, Washington State Public Health Association

Swimming Pool Operator's Text, Florida Swimming Pool Operator's Association

Chlorine Manual, The Chlorine Institute

Betz Handbook of Industrial Water Conditioning

Proceedings of Rudolphs Research Conference, Rutgers - The State University, New Brunswick, N. J.

Theoretical Aspects of Diatomite Filtration, Dr. E. Robert Baumann, Iowa

State University, Ames, Iowa

Alkalinity, pH and Chlorination, F. J. McIntyre

Chemistry of the pH Factor, Professor J. Carroll Morris, Harvard University